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Research Establishment Risö

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June, 1971 Risö Report No. 245

Environmental Radioactivity in Denmark in 1970

by

A. Aarkrog and J. Lippert

The Danish Atomic Energy Commission
Research Establishment Risö
Health Physics Department

Abstract

The present report deals with the measurement of fall-out radioactivity in Denmark in 1970. Sr-90 was determined in samples from all over the country of precipitation, soil, ground water, surface water, sea water, grass, dried milk, fresh milk, grain, bread, potatoes, vegetables, fruit, total diet, drinking water, and human bone. Furthermore Sr-90 was determined in local samples of air, rain water, grass, sea plants, fish, and meat. Cs-137 was determined in soil, milk, grain products, potatoes, vegetables, fruit, total diet, and meat, and Cs-137 was measured by whole-body counting in persons from a control group at Risö. Estimates of the mean contents of radiostrontium and radiocaesium in the human diet in Denmark in 1970 are given. The γ-background was measured regularly at locations around Risö, at ten of the State experimental farms and in an area in Zealand, one in Jutland where future nuclear power plants might be located and along the shores of the Great Belt. Finally the report includes, as previously, regular surveys of environmental samples from the Risö area.

STATENS TRYKNINGSKONTOR
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ABBREVIATIONS AND UNITS

FP	Fission products
pCi	picocurie, 10^{-12} Ci, μμCi
nCi	nanocurie, 10^{-9} Ci, mμCi
mCi	millicurie, 10^{-3} Ci
MPC	maximum permissible concentration
c/min	counts per minute
d/min	disintegrations per minute
c/h	counts per hour
μR	micro-roentgen, 10^{-6} roentgen
S. U.	pCi Sr-90/g Ca.
O. R.	observed ratio
M. U.	pCi Cs-137/g K.
V	vertebrae
m	male
f	female
n Sr	natural (stable) Sr
eqv. μg	equivalents g uranium: activity as from 1 μg U(~90 d/h)
eqv. mg KCl	equivalents mg KCl: activity as from 1 mg KCl (~0.88 d/min)
S. D.	standard deviation: $\sqrt{\frac{\Sigma(x-x_i)^2}{(n-1)}}$
S. E.	standard error: $\sqrt{\frac{\Sigma(x-x_i)^2}{n(n-1)}}$
U. C. L.	upper control level
L. C. L.	lower control level
Δ	one standard deviation due to counting
S. S. D.	sum of squares of deviation: $\Sigma(x-x_i)^2$
f	degrees of freedom
s^2	the variance
v^2	the ratio between the variance in question and the residual variance
P	probability fractile of the distribution in question
η	coefficient of variation

Samples:

H:	sea water
J:	soil
L:	air
B:	bed soil
Å:	eel
PG:	grass
PH:	sea plants
D:	drain water
S:	waste water
R:	precipitation
M:	milk

1. INTRODUCTION

1.1.

The present report is the fourteenth of a series of periodical reports (cf. ref. 1) dealing with measurements of radioactivity in Denmark.

The programme is nearly unchanged as compared with 1969. Soil samples were collected down to a depth of 30 cm (earlier 20 cm). Samples of fresh water were collected from Danish streams. No samples of human milk were collected in 1970.

1.2.

The methods of radiochemical analysis[2-4] and the statistical treatment of the results[5] are still based on the principles established in previous reports[1].

1.3.

The report does not include detailed tables of the total β measurements from the environmental control of the Risö site. These tables are available in the form of microcards at the library of the Danish Atomic Energy Commission at Risö.

1.4.

The report contains no information as regards sample collection and analysis except in the cases where these procedures have been altered.

1.5.

In 1970 the personnel of the Environmental Control Section of the Health Physics Department consisted of one chemist, ten laboratory technicians, two men for sample collection, and two women for washing-up. As in the previous years, important assistance was obtained from the Section for Electronics Development, not only in the maintenance of the counting equipment, but also in the interpretation of the γ-spectra. The computer programmes (cf. 2) used in the calculations of Sr-90 as well as in the γ-analysis were developed by the Section for Electronics Development.

1.6.

The composition of the Danish average diet used in this report is identical with that proposed in 1962 by the nutritional consultant to the Atomic Energy Commission, Professor E. Hoff-Jørgensen, Ph.D.

2. ORGANIZATION AND FACILITIES[1,6,8]

Our whole-body counter (cf. Risö Report No. 85[1]) has been equipped with an 8 x 4 inch NaJ crystal instead of the old 3 x 3 inch crystal. This has improved the counting efficiency and made it possible still to measure in humans the Cs-137 levels from fall-out. The old 256-channel TMC analyser used in the whole-body countings and in the Cs-137 determinations on milk and diet samples has been replaced by a 1024-channel Nuclear Data analyser.

This analyser is operated as four 256-channel analysers each connected to a NaJ crystal, one of these being the whole-body counter. The read-out unit is a tape puncher and the tape is transferred to the memory of a 1024-channel HP analyser connected to a B9100 HP-calculator. This calculator has been programmed for the calculation of Y-spectra.

The NaJ-spectra are evaluated by a modified version of a method given by P. Quittner[7]. The photo-peak area is calculated as the sum of a certain number of channels around the peak minus a background, which is obtained from a polynomial fit to the slope and average value of a number of channels on both sides of the peak. Our modification of the method consists in a neglection of the slope on the lower side of the peak, which we find gives a better fit to the background for weak samples.

The same method applies to Ge-Li spectra for determination of Cs and K. Other calculator programmes are written for determination of up to 10 stronger peaks in a spectrum by subtracting a simple average of the background on each side of the peaks.

The HP-calculator has further been programmed for the calculation of Sr-90 and Sr-89 from radiochemical analyses. From the countings of Y-90 the programme extrapolates the activity to the time of separation of Y from Sr. From the deviation from an exponential decay and from the total counts of the Y-sample, the relative standard deviation of the counting is calculated.

3. RISÖ ENVIRONMENTAL MONITORING IN 1970

3.1. Gross β activity

3.1.1. Sea Water

Fig. 3.1.1.1 shows the sample locations in Roskilde Fjord. Fig. 3.1.1.2 shows the control chart for H I. The yearly mean for H I in 1970 was 54 eqv. mg KCl/2.5 g (in 1969: 53), for H III-VI: 56 eqv. mg KCl/2.5 g (in 1969: 52) and for H VII-X: 55 eqv. mg KCl/2.5 g (in 1969: 53). Fig. 3.1.1.3 shows the mean levels of radioactivity in sea salt since 1957.

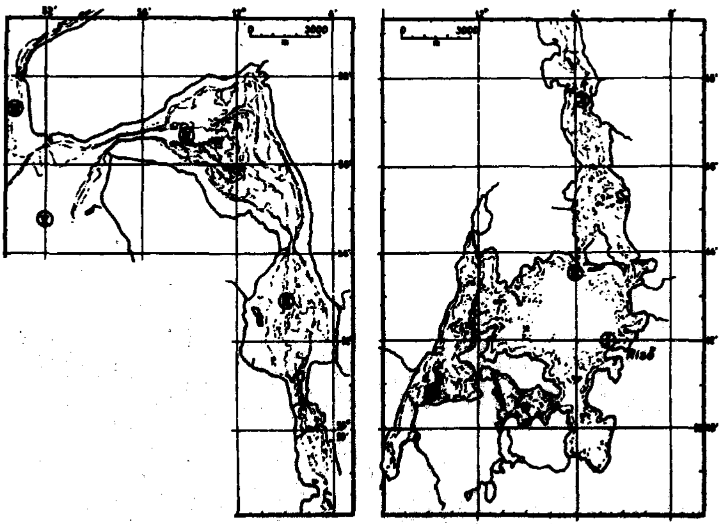


Fig. 3.1.1.1. Roskilde Fjord.

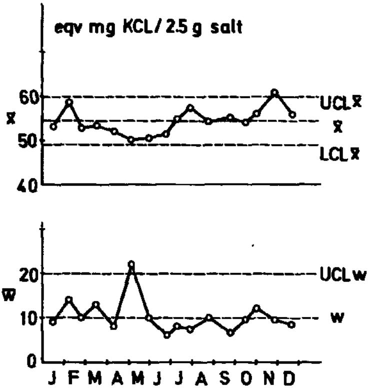


Fig. 3.1.1.2. Control chart for HI, 1970

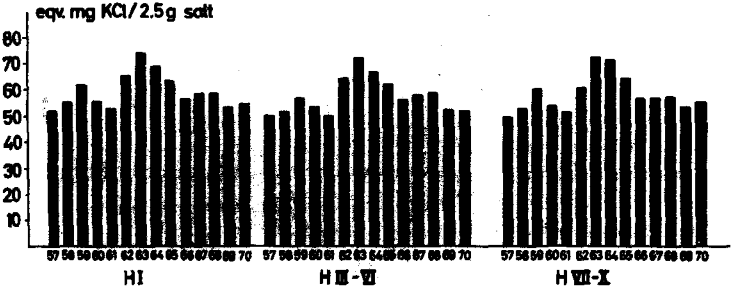


Fig. 3.1.1.3. Mean radioactivity in sea water, 1957-70

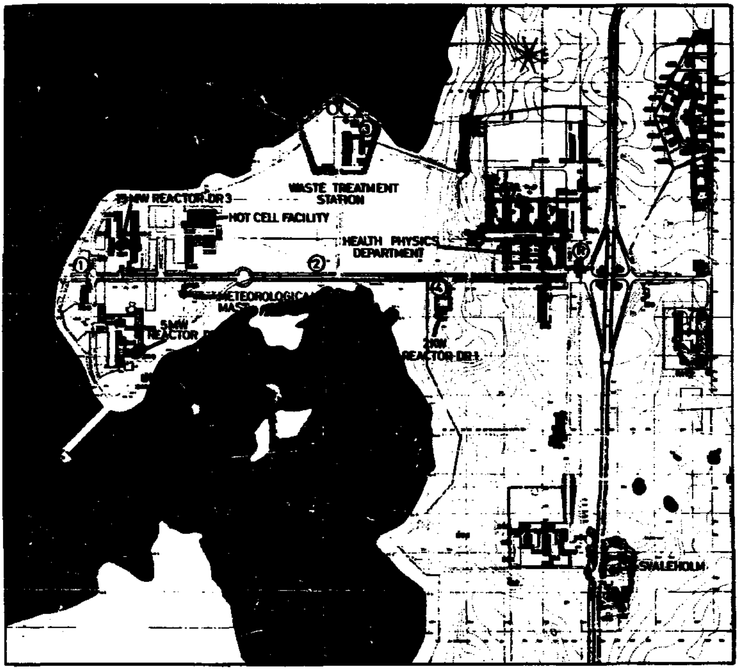


Fig. 3.1.2.1. The Risö Research Establishment.

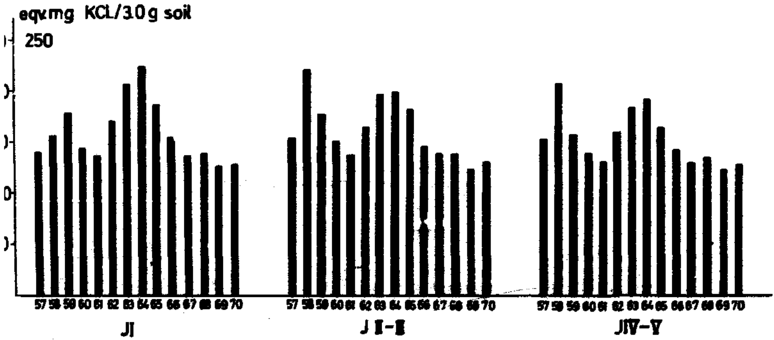


Fig. 3.1.2.3. Mean radioactivity in soil, 1957-70

3.1.2. Soil

Figs. 3.1.2.1 and 3.1.2.2 (the coloured map) show the sample locations for land samples in the environment of Risö.

The yearly mean for J I in 1970 was 129 eqv. mg KCl/3.0 g soil (in 1969: 129), for J II-III: 130 eqv. mg KCl/3.0 g (in 1969: 127) and for JIV-V: 129 eqv. mg KCl/3.0 g (in 1969: 127). Fig. 3.1.2.3 shows the mean levels of radioactivity in soil since 1957.

3.1.3. Air

Fig. 3.1.3.1 shows the diagram for FP activity in air samples in 1970. The mean value for the year was 0.14 eqv. mg KCl/m^3 as compared with 0.27 eqv. mg KCl/m^3 in 1969.

Fig. 3.1.3.2 shows the mean FP levels in air since 1957.

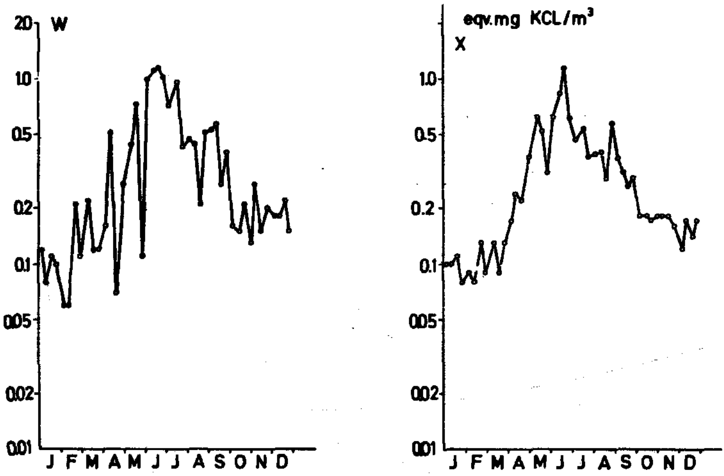


Fig. 3.1.3.1. Control chart for LF, 1970

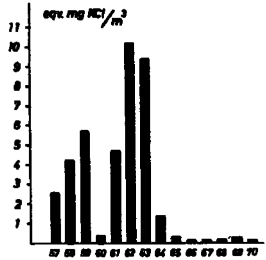


Fig. 3.1.3.2. Mean radioactivity in air, 1957-70

3.1.4. Bed Soil from the Fjord

The mean activity in bed soil B I was 157 eqv. mg KCl/3.0 g ash in 1970 as compared with 136 eqv. mg KCl/3.0 g in 1969. Fig. 3.1.4.1 shows the mean levels for B I since 1957.

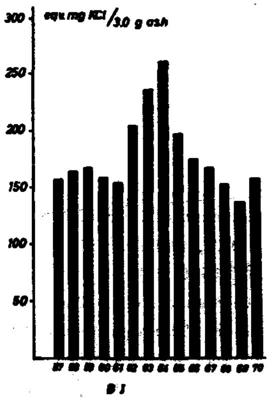


Fig. 3.1.4.1. Mean radioactivity in bed soil, 1957-70

3.1.5. Fish

No fish samples from Roskilde Fjord were measured in 1970.

3.1.6. Grass

The mean values were in 1970 for PG I: 25 eqv. mg KCl/0.1 g grass ash (in 1969: 23), for PG II-III: 25 eqv. mg KCl/0.1 g (in 1969: 22) and for PG IV-V: 24 eqv. mg KCl/0.1 g (in 1969: 21). Fig. 3.1.6.1 shows the mean activities in grass ash since 1957.

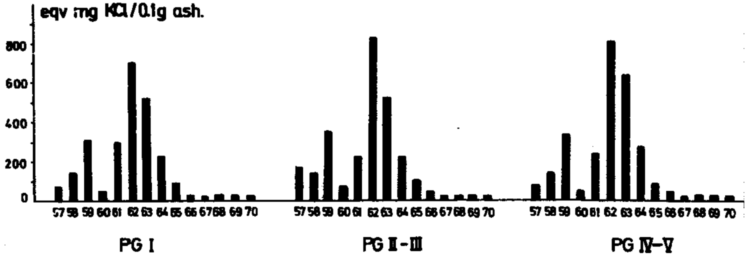


Fig. 3.1.6.1. Mean FP-radioactivity in grass ash, 1957-70

3.1.7. Sea Plants

The FP level in 1970 in Fucus vesicolosus (PH I) was 7 eqv. mg KCl/0.1 g ash (only 1 sample) (1.0 in 1969).

3.1.8. Fresh Water

Fig. 3.1.8.1 contains the control charts for S (cf. fig. 3.1.2.2). The yearly means for D I, D II, D IV, and S in 1970 were 42 eqv. mg KCl/l (1969: 61), 28 eqv. mg KCl/l (1969: 25), 49 eqv. mg KCl/l (1969: 33), and 609 eqv. mg KCl/l (1969: 56) respectively. The high average value was due to a single sample in December. The high level found in this sample collected on December 30, 1970, was presumably due to a shortlived ($t_{1/2}$ < 14 d) particulate activity in the counting sample in question. The S-35 content of the sample was 10% of the total activity. If we omit this value the annual mean value is 157 eqv. mg KCl/l. Fig. 3.1.8.2 shows the activity in drainage water (D) and sewage water (S). The surplus activity in sewage water was, as in 1969, due to minor amounts of S-35 released from the Waste Treatment Station (cf. fig. 3.1.8.1).

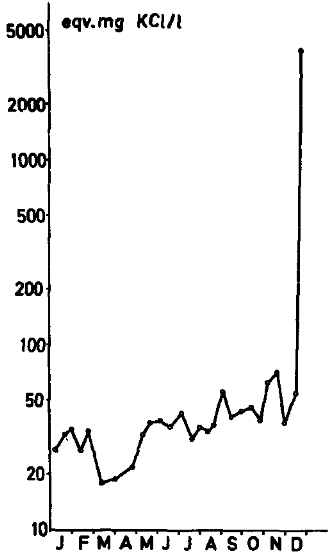


Fig. 3.1.8.1. Control chart for S, 1970

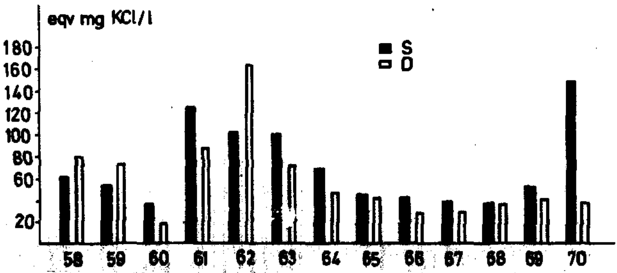


Fig. 3.1.8.2. Mean radioactivity in fresh water, 1958-70

3.1.9. Rain Water

Figs. 3.1.9.1 and 3.1.9.2 show the specific FP level in and the total fall-out from rain water collected daily at Risö in 1970. The total fall-out in 1970 was measured at $0.042 \cdot 10^6$ eqv. mg KCl/m^2, and the annual mean concentration in rain water at Risö was 83 eqv. mg KCl/l. In 1969 the corresponding figures were $0.053 \cdot 10^6$ and 134 respectively.

Fig. 3.1.9.3 shows the specific activity in rain water since 1957.

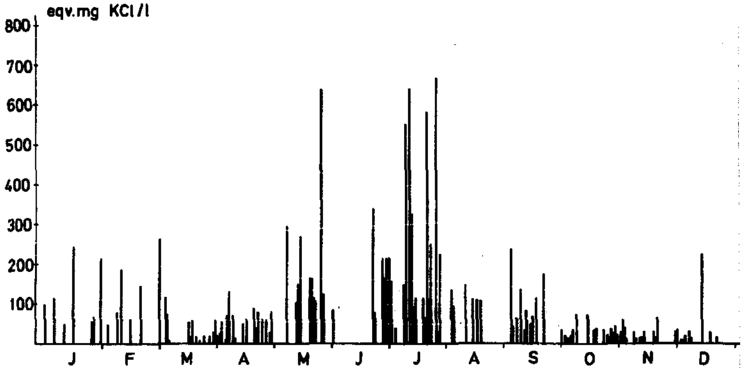


Fig. 3.1.9.1. Concentration of β-activity in 1970

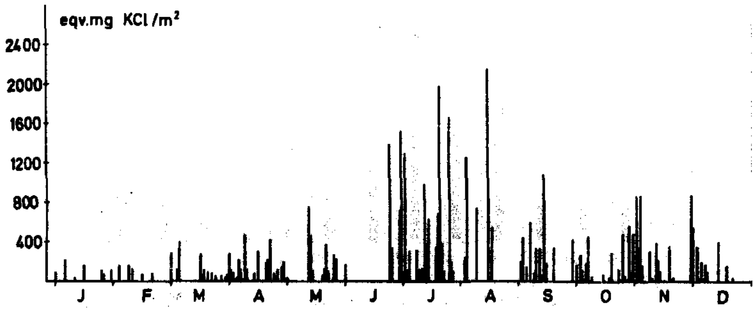


Fig. 3.1.9.2. Total fall-out from precipitation in 1970

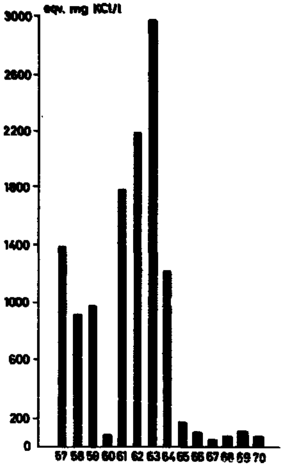


Fig. 3.1.9.3. Specific activity in precipitation, 1957-70

3.2. Radiochemical β-Analysis

3.2.1. Air

In recent years[1)] we have in the daily airfilters (paper) observed a systematic lower activity than in the monthly samples (glass-fibre filters). We have not earlier seen this difference, and we think it is due to a reduced filter efficiency of the paperfilters used in recent years. Since April we have alternated in our daily airsampler between glass-fibre filters and paperfilters (every other day we used a glass-fibre filter instead of a paper-filter). Table 3.2.1 shows the results. The mean ratio between the daily glass-fibre filters and paperfilters was 1.3 ± 0.2 (1 SE). Hence we believe that the efficiency of the paperfilters may be somewhat less than 100% (glass-fibre filters have an efficiency of nearly 100%). However, the difference between the two filters is not statistically significant, and as was the case last year, we will report the mean air activity level for 1970 as the mean of the monthly glass-fibre filter collection and the daily paperfilter sampling: 2.1 ± 0.2 pCi Sr-90/$10^3 m^3$ i.e. 50% higher than the 1969 level. The mean peak activity of the two collections in 1970 was measured in June to be 6.2 pCi Sr-90/$10^3 m^3$. Sr-90 from the Chinese tests was detectable in most months of the year.

Fig. 3.2.1.1 shows the Sr-90 levels in air since 1957.

Table 3.2.1

Sr-90 and Sr-89 in air collected at Risø in 1970
pCi Sr-90/$10^3 m^3$

Month	Daily air filters		Monthly air filters (glass-fibre filters)	Sr-89/Sr-90 mean ratio
	Glass fibre	Paper		
Jan.	-	0.7	0.7	-
Feb.	-	0.6	0.7	1.6
Mar.	-	0.5	1.3	0.7
Apr.	1.7	1.2	1.4	-
May	4.6	3.4	4.5	3.3
June	5.4	5.9	6.5	2.8
July	3.7	2.9	3.3	2.1
Aug.	3.4	3.6	3.9	1.0
Sep.	2.0	1.8	2.2	0.5
Oct.	0.9	1.8	1.6	0.5
Nov.	1.0	1.0	1.1	2.5
Dec.	1.5	0.6	0.8	1.4
1970		1.9	2.3	

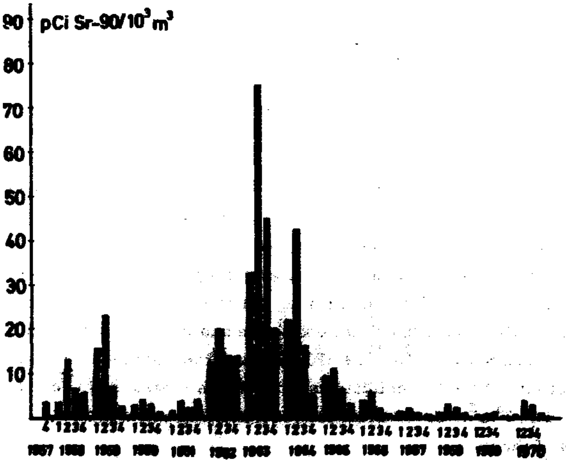


Fig. 3.2.1.1. Sr-90 in air, 1957-70

Table 3.2.2

Sr-90 in grass from Zealand, 1970

	pCi Sr-90/g ash	pCi Sr-90/g Ca
Jan. - Mar.	2.11	47
Apr. - June	1.24	26
July - Sep.	4.86	67
Oct. - Dec.	4.45	62
1970	3.16	50
The error term is the S.E. of double determinations		

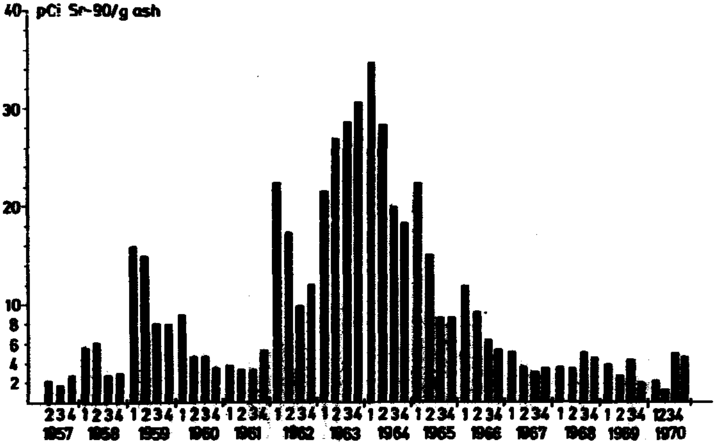


Fig. 3.2.2.1, Sr-90 in grass ash, 1957-70

3.2.2. Grass

Table 3.2.2 shows the Sr-90 content in grass ash from Zealand in 1970. The mean Sr-90 activity was 3.2 pCi Sr-90/g ash or 50 S.U. as compared with 3.2 pCi/g ash or 54 S.U. in 1969, i.e. the 1970 level was equal to the 1969 level. Fig. 3.2.2.1 shows the Sr-90 levels in grass since 1957.

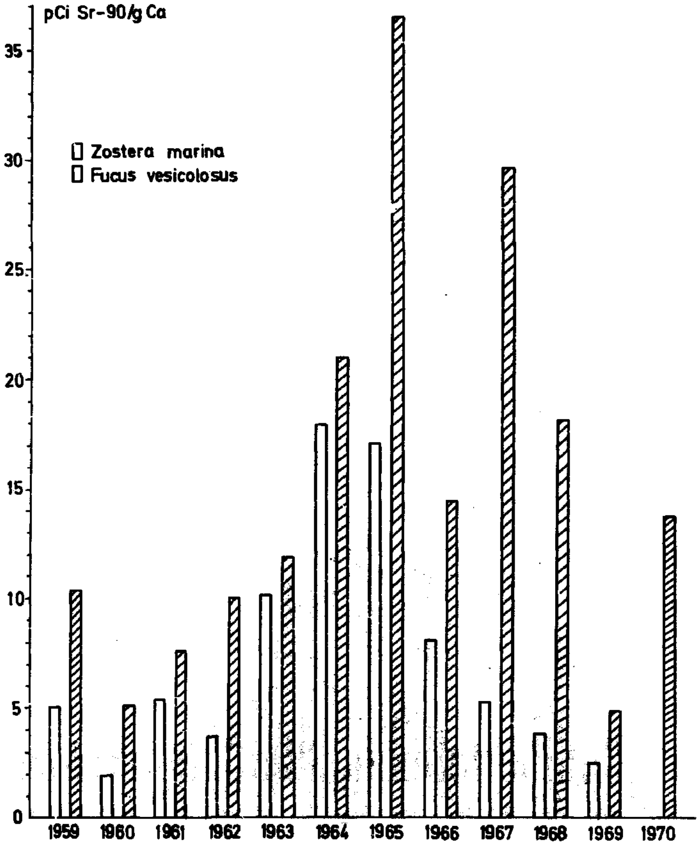


Fig. 3.2.3. Sr-90 in sea plants, 1959-70

3.2.3. Sea Plants

Only one sample was obtained in 1970. From location I a sample of Fucus vesicolosus was collected on April 30. It contained 1.0 pCi Sr-90/g ash and 13.6 pCi Sr-90/g Ca.

Fig. 3.2.3 shows the S.U. levels in sea plants since 1959.

3.2.4. Rain Water

Table 3.2.4.1 shows the radiostrontium level in rain water collected at Risö in 1970. The total Sr-90 fall-out in 1970 was 0.86 mCi Sr-90/km^2 (519 mm precipitation), and the mean concentration in the rain water was 1.7 pCi Sr-90/l. In 1969 we measured 0.82 mCi Sr-90/km^2 (429 mm precipitation and 1.9 pCi Sr-90/l, i.e. the 1970 levels were nearly equal to those of 1969.

Fig. 3.2.4.1 shows the Sr-90 levels in rain water since 1959.

At five sampling locations (1-5) in zone 1 (cf. fig. 3.1.2.1) ion-exchange columns collected monthly samples of precipitation along with the bottle collectors. The columns have been described earlier (Risö Report No. 41[1]) and are similar to those used in the U.S.A. by HASL[4]. The purpose of this collection is to compare the efficiency of the ion-exchange columns with that of rain bottles as collectors of fall-out. Table 3.2.4.2 shows the results.

Table 3.2.4.3 shows Sr-90 determined in monthly samples of rain water collected daily in the 1 m^2 rain collector (R) (cf. fig. 3.1.2.1) at Risö. The

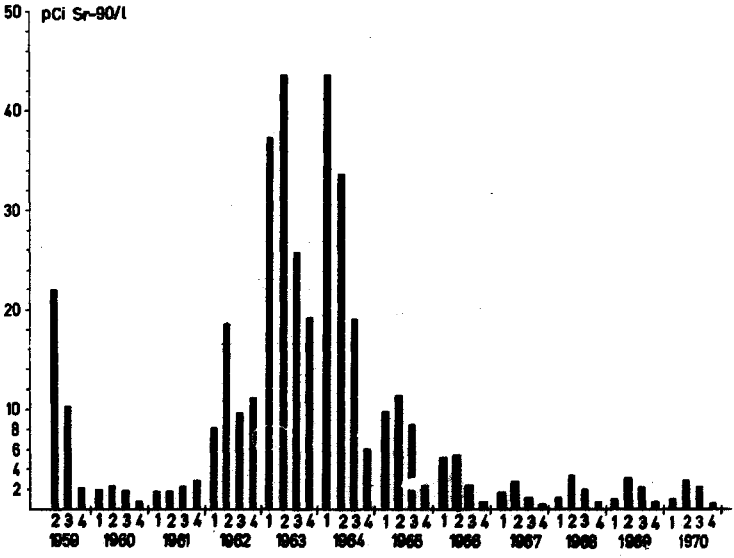


Fig. 3.2.4.1. Sr-90 in precipitation, 1959-70

Table 3.2.4.1

Sr-90 in monthly samples of rain water collected in rain bottles at Risö in 1970 (sampling area 0.236 m^2)

Month	mm	pCi Sr-90/l	mCi Sr-90/km^2
Jan.	15	1.00	0.015
Feb.	6	1.38	0.008
Mar.	52	0.99	0.052
Apr.	63	1.22	0.076
May	26	5.27	0.137
June	22	5.05	0.113
July	58	3.28	0.190
Aug.	45	2.07	0.093
Sep.	51	1.36	0.069
Oct.	70	0.72	0.050
Nov.	69	0.48	0.033
Dec.	42	0.57	0.024
1970	519	1.66	0.860

$$\overline{X} = \frac{\Sigma \text{mCi/km}^2 \cdot 10^3}{\Sigma \text{ mm}} \text{ pCi/l}$$

Table 3.2.4.2

Sr-90 in monthly samples of rain water collected in ion-exchange column collectors at Risö in 1970 (sampling area 0.325 m^2)

Month	mm	pCi Sr-90/l	mCi Sr-90/km^2
Jan.	11	0.84	0.010
Feb.	3	1.17	0.004
Mar.	39	0.62	0.024
Apr.	58	1.01	0.059
May	20	3.26	0.065
June	10	9.33	0.093
July	57	2.22	0.127
Aug.	45	1.83	0.083
Sep.	49	0.97	0.048
Oct.	76	1.00	0.076
Nov.	74	0.38	0.028
Dec.	36	0.48	0.017
1970	478	1.33	0.634

Table 3.2.4.3

Sr-90 in monthly samples of rain water collected daily in a 1 m^2 collector at Risö in 1970

Month	mm	pCi Sr-90/l	mCi Sr-90/km^2
Jan.	8	2.43	0.018
Feb.	7	0.85	0.006
Mar.	49	1.14	0.056
Apr.	57	1.30	0.074
May	20	3.52	0.069
June	21	3.40	0.072
July	59	2.55	0.150
Aug.	44	1.81	0.079
Sep.	48	1.27	0.062
Oct.	62	0.56	0.035
Nov.	89	0.51	0.045
Dec.	29	0.53	0.015
1970	Σ 493	$\bar{x}$: 1.38	Σ 0.68

Table 3.2.4.4

Analysis of variance of mm precipitation at Risö in 1970 (from tables 3.2.4.1 - 3.2.4.3)

Variation	SSD	f	s^2	v^2	P
Betw. samplers	71.96	2	35.9805	1.33	-
Betw. months	17850	11	1623	60	>99.95 %
Remainder	595	22	27.05		
η = 0.13					

Table 3.2.4.5

Analysis of variance of ln pCi Sr-90/l precipitation collected at Risö in 1970 (from tables 3.2.4.1 - 3.2.4.3)

Variation	SSD	f	s^2	v^2	P
Betw. samplers	0.1381	2	0.0691	0.80	-
Betw. months	19.3591	11	1.7599	20.28	>99.95 %
Remainder	1.9105	22	0.0868		
η = 0.30					

Table 3.2.4.6

Analysis of variance of ln mCi Sr-90/km^2 from precipitation at Risö in 1970 (from tables 3.2.4.1 - 3.2.4.3)

Variation	SSD	f	s^2	v^2	P
Betw. samplers	0.6797	2	0.3399	5.46	>97.5 %
Betw. months	28.8076	11	2.6189	42.10	>99.95 %
Remainder	1.3682	22	0.0622	-	-
η = 0.25					

monthly samples were subjected to ion exchange in the laboratory on a column similar to those used in the field sampling described above, and analysed for Sr-90.

Precipitation was further collected at eight stations located in the meteorological mast at Risö (cf. 8.1). Thus we have four sampling systems for precipitation covering the Risö area: 1: the 1 m^2 collector (table 3.2.4.3); 2: the eight rain bottles at ground level (table 3.2.4.1); 3: the five ion exchange collectors (table 3.2.4.2), and 4: the eight rain bottles in the meteorological mast (table 8.1.1). Tables 3.2.4.4 - 3.2.4.6 show the analysis of variance of the three first-mentioned systems (a similar analysis was carried out in the previous years).

In 1970 we replaced our polyethylen funnels in our precipitation collectors at Risö by PVC funnels with greater sampling areas than had the old funnels.

3.2.5. Milk from a farm near Risö

Table 3.2.5 shows the radiostrontium and caesium-137 contents in milk collected in 1970 from a farm near Risö. The mean level was 3.4 S.U. as compared with 5.1 S.U. in 1969. Fig. 3.2.5 shows the Sr-90 levels in "Risö" milk since 1959. The caesium-137 mean level was also lower than in 1969 (6.8 pCi/l against 9.1 pCi/l in 1969).

Table 3.2.5

Sr-90 and Cs-137 in milk from Risö[x] in 1970

Months	pCi Sr-90/g Ca	pCi Cs-137/g K	pCi Cs-137/l
Jan.-Mar.	3.5	4.64	7.3
Apr.-June	3.5	5.13	8.2
July-Sep.	3.3	3.34	5.3
Oct.-Dec.	3.4	4.14	6.6
1970	3.4	4.31	6.8

[x] The milk was collected from the milk producing farm nearest to Risö

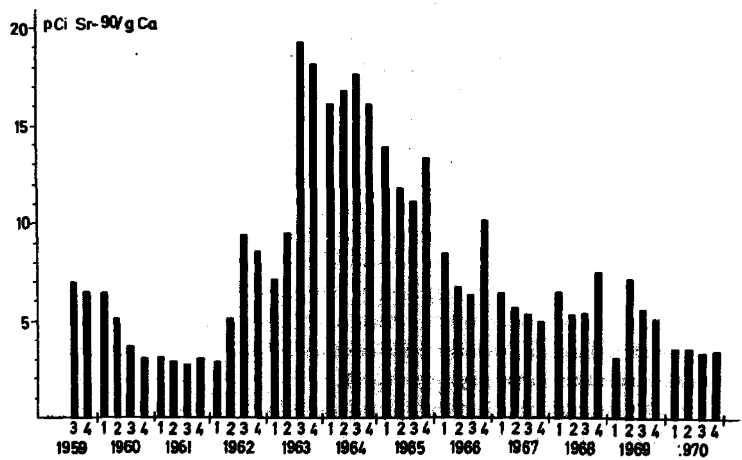


Fig. 3.2.5. Sr-90 in milk from Risö neighbourhood

Table 3.3.1

Cs-137 in glass-fibre air filters collected twice a week at Risö in 1970
pCi Cs-137/$10^3 m^3$

Month	pCi/$10^3 m^3$
Jan.	0.9±0.2
Feb.	1.1±0.1
Mar.	1.6±0.4
Apr.	2.7±0.8
May	5.4±1.1
June	8.3±2.5
July	5.4±0.1
Aug.	5.6±0.2
Sep.	4.1±0.4
Oct.	2.3±0.2
Nov.	2.5±0.3
Dec.	1.2±0.0
1970	3.4

The error term is the S. E. of the mean of the activity found in the first and the second half of the month.

3.3. γ Spectroscopy of Air Samples

As in 1962-69, half-weekly samples of air were collected by means of the air sampler described in Risö Report No. 23[1]. Parts of the half-weekly filters were bulked into half-monthly samples and measured on a 30 cm^3 Ge(Li) detector[8]. Table 3.3.1 shows the results. The peak value was observed in the second half of June (cf. also Sr-90 in air, table 3.2.1). The mean level in 1970 was 40% higher than the 1969 mean.

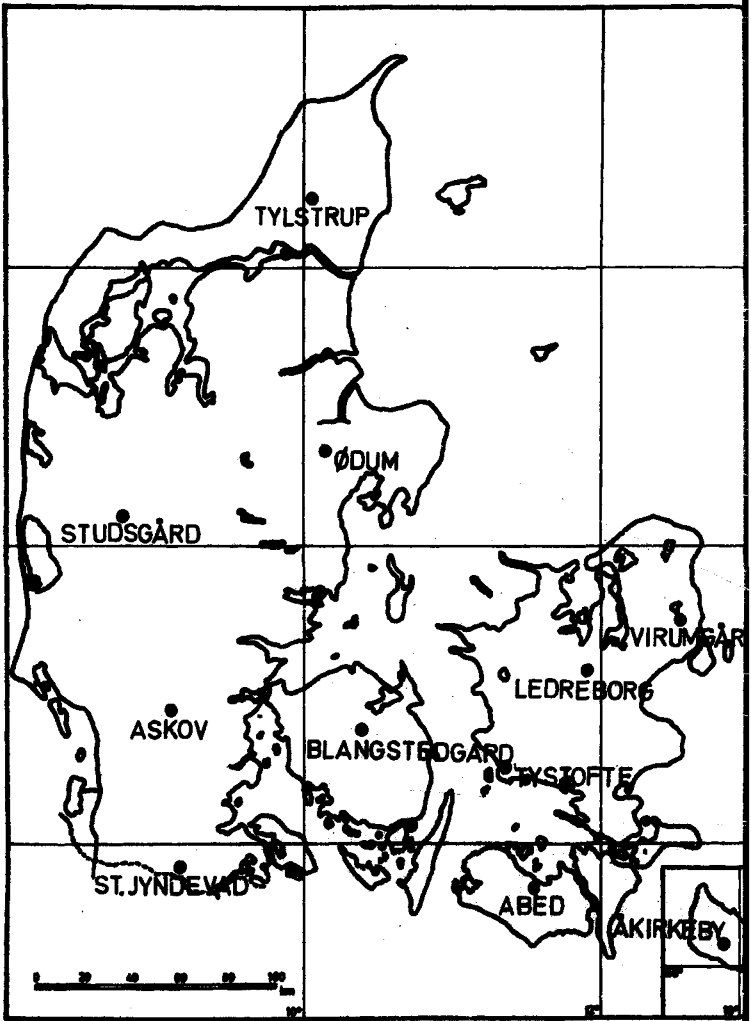


Fig. 4.1.1. State experimental farms in Denmark.

4. RADIOSTRONTIUM AND RADIOCAESIUM IN PRECIPITATION, SOIL AND GROUND WATER IN DENMARK IN 1970

4.1. Sr-90 and Sr-89 in Precipitation

Samples of rain water were collected in 1970 from the ten State experimental farms (cf. fig. 4.1.1) in accordance with the principles laid down in Risö Report No. 63, p. 51[1].

Table 4.1.1 shows the results of the Sr-90 determinations and tables 4.1.2 and 4.1.3 the analysis of variance of the results. The variation with time was highly significant (P > 99.95%). The maximum specific activity occurred in May-June, when the mean content in precipitation was 5.73 pCi Sr-90/l (cf. also the air measurements in 3.2.1). The maximum fall-out rate was found in July-August, the mean fall-out rate in that period being 0.55 mCi Sr-90/km^2. Tables 4.1.2 and 4.1.3 show that the variation between locations was highly significant. The specific activity for 1970 was 3.18 pCi Sr-90/l at Ødum, while only 1.36 pCi Sr-90/l was measured at Blangstedgård. The 1970 mean levels for ten State experimental farms

Table 4.1.1

Sr-90 fall-out in Denmark in 1970

od	Unit	Tylstrup	Studsgård	Ødum	Askov	St. Jyndevad	Blangstedgård	Tystofte	Virumgård	Abed	Åkirkeby	Mean	Ledreborg
-Feb.	pCi/l	2.15	1.65	1.71	2.21	1.48	0.84	2.09	1.12	1.01	4.18	1.69	0.97
	mCi/km^2	0.075	0.064	0.030	0.092	0.067	0.030	0.031	0.026	0.028	0.048	0.049	0.018
. -Apr.	pCi/l	1.97	2.05	1.66	3.00	3.42	1.38	2.11	1.36	1.64	2.97	2.22	1.32
	mCi/km^2	0.24	0.31	0.17	0.56	0.54	0.15	0.21	0.19	0.19	0.30	0.266	0.10
-June	pCi/l	6.72	5.80	9.41	6.61	3.16	2.88	4.96	5.75	4.58	12.11	5.73	5.18
	mCi/km^2	0.30	0.51	0.44	0.66	0.31	0.18	0.31	0.31	0.21	0.38	0.361	0.25
-Aug.	pCi/l	5.76	3.50	5.63	4.62	4.44	2.59	6.48	3.42	2.94	6.65	4.48	2.94
	mCi/km^2	0.59	0.52	0.49	0.73	0.56	0.23	0.78	0.46	0.24	0.58	0.547	0.25
-Oct.	pCi/l	2.16	1.36	2.11	1.66	1.77	0.91	1.57	1.06	1.04	1.85	1.59	0.90
	mCi/km^2	0.38	0.38	0.26	0.42	0.36	0.19	0.22	0.19	0.15	0.33	0.283	0.11
-Dec.	pCi/l	0.38	0.89	1.11	0.75	0.85	0.60	0.85	0.58	0.51	1.16	0.81	0.62
	mCi/km^2	0.106	0.181	0.106	0.132	0.163	0.076	0.093	0.086	0.084	0.156	0.122	0.071
)	pCi/l Σ	2.79	2.20	3.18	2.82	2.56	1.36	3.00	1.87	1.56	3.11	2.44	1.73
	mCi/km^2 Σ	1.66	1.92	1.50	3.69	2.90	0.36	1.64	1.28	0.90	1.82	1.65	0.80
precipitation Σ		596	873	472	918	890	632	647	684	578	586	677	484

Table 4.1.2

Analysis of variance of ln pCi Sr-90/l precipitation in 1970
(from table 4.1.1)

Variation	SSD	f	s^2	v^2	P
Betw. locations	4.6122	9	0.5125	10.19	>99.95 %
Betw. months	25.7938	5	5.1588	102.56	>99.95 %
Remainder	2.2627	45	0.0503		
η = 0.23					

Table 4.1.3

Analysis of variance of ln mCi Sr-90/km² precipitation in 1970
(from table 4.1.1)

Variation	SSD	f	s^2	v^2	P
Betw. locations	6.9346	9	0.7705	14.32	>99.95 %
Betw. months	38.9410	5	7.7882	144.7621	>99.95 %
Remainder	2.4218	45	0.0538		
η = 0.23					

were 1.65 mCi Sr-90/km^2 and 2.44 pCi Sr-90/l. In Appendix A the country mean level (area weighted) is estimated to be 1.9 mCi Sr-90/km^2 for a mean precipitation amount of 750 mm (area weighted), i.e. 1.35 times the fall-out rate in 1969.

The Sr-89/Sr-90 ratios at the ten stations are shown in table 4.1.4. By the end of the year fresh fall-out began to appear, probably from the Chinese test explosion in October 1970 (cf. also fig. 4.1.2).

A comparison between the amounts of precipitation found in the rain gauges used by the Danish Meteorological Institute and the amounts collected in our rain bottles at the same locations showed that in 1970 our bottles collected 90 per cent (1 SE: 3%) of the amount measured in the rain gauges. The difference between the two systems was, as also observed in 1969, most pronounced during the winter months of January and February, where the percentage was only 50. The implications of this were discussed in Risø Report No. 220[1].

Table 4.1.4

Sr-89/Sr-90 in fall-out collected in 1970

Period	Tylstrup	Studsgård	Ødum	Askov	St. Jyndevad	Blangstedgård	Tystofte	Virumgård	Abed	Åkirkeby	Ledreborg	Mean
Jan.-Feb.	1.1	1.4	2.1	1.9	3.2	2.3	1.6	1.4	2.0	2.8	1.2	1.9±0.2
Mar.-Apr.	2.0	2.7	1.9	3.0	2.6	1.7	2.0	0.7	2.4	0.4	3.1	1.9±0.3
May-June	2.5	3.1	2.6	2.1	1.7	4.3	2.9	3.1	1.1	4.7	0.8	2.7±0.4
July-Aug.	0.2	0.9	0.2	1.3	1.0	0.3	0	0.7	1.3	0	0.7	0.6±0.2
Sep.-Oct.	1.7	1.2	1.6	2.0	1.7	1.2	1.7	1.3	0.9	1.6	2.1	1.5±0.1
Nov.-Dec.	1.3	0.7	1.6	1.3	0.7	0.8	1.4	1.2	2.4	1.5	0.9	1.3±0.2

The error term is the S.E. of the mean

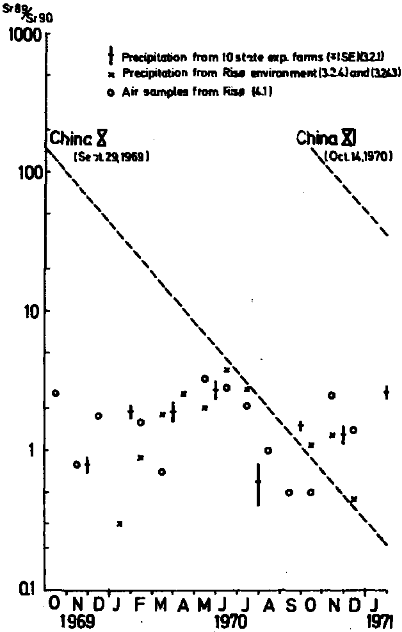
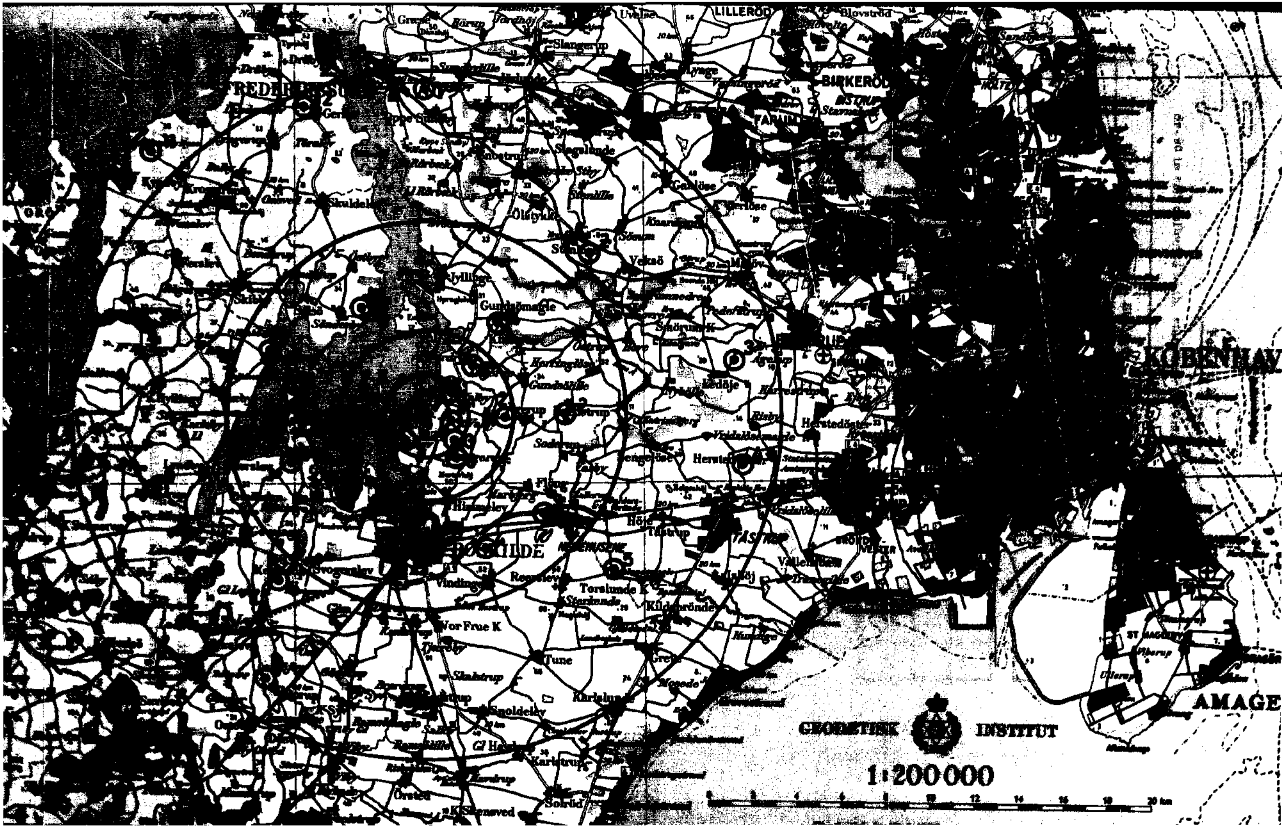


Fig. 4.1.2. Sr-89/Sr-90 in precipitation and air samples 1969-70

4.2. Sr-90 and Cs-137 in Soil

As in previous years, soil was collected with a view to estimating the accumulated fall-out. As previously, the samples were collected in September from uncultivated areas all over the country (cf. fig. 4.1.1). But contrary to other years were the samples in 1970 collected down to a depth of 30 cm (instead of 20 cm).

Table 4.2.1 shows the Sr-90 results from the ten State Experimental Farms. The mean value in September 1970 was 55 mCi Sr-90/km^2. However, this value should be recalculated to a depth of 20 cm before we compare the results of the previous years. In a special study performed in 1970, we found that 83% of the activity found from 0-30 cm was present from 0-20 cm. Thus 46 mCi Sr-90/km^2 was present down to the old sampling depth of 20 cm by September 1970. This is 92% of the level measured in 1969.



LILLERØD
Blovstrød
BIRKERØD
FARUM
Slangerup
Uvelse
Stenløse
Ølstykke
Veksø
Gundsømagle
Jyllinge
Ledøje
Herstedøster
ROSKILDE
Vindinge
Reerslev
Torslunde
Kildebrønde
Vor Frue K
Tune
Karlslunde
Snoldelev
Karlstrup
Solrød
Hedehusene
Høje Tåstrup
TÅSTRUP
Vallensbæk
Hundige
Greve
Mosede
KØBENHAV
AMAGE
GEODÆTISK INSTITUT
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Table 4.2.1

Sr-90 in soil collected at the state experimental farms in September 1970

	Tylstrup	Studsgård	Ødum	Askov xx)	St. Jyndevad xx)
mCi Sr-90/km^2	52±4	55±8	49±2	59±5	74±5
pCi Sr-90/kg	117±11	156±24	118±5	146±14	155±10

Blangstedgård xx)	Tystofte	Virumgård	Abed	Åkirkeby	Mean	SD	SE
67±6	48±1	50±6	58±2	47±2	55	8	3
140±14	100±1	116±14	233±8	116±4	140	37	12

All determinations were double, except xx) which were triple.
The error term is the S.E. of the mean

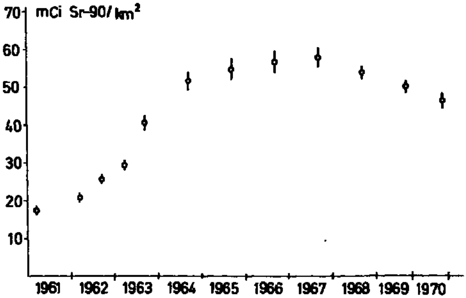

Fig. 4.2. Accumulated Sr-90 fallout in Danish soil, 1961-70
0-20 cm (1 S.E. indicated)

From precipitation data[1,17], the accumulated fall-out in Denmark in 1970 was calculated to 54 mCi/km^2, i.e. nearly equal to the level found in table 4.2.1.

Thus we have found indication of a movement of the Sr-90 activity in the soil to a greater depth than 20 cm, but hardly further down than 30 cm.

Table 4.2.2 shows the Sr-90 levels soil locations in Zealand, mainly in the neighbourhood of Risö.

Table 4.2.2

Sr-90 in soil collected in Zealand in September 1970

	Risö	Roskilde Fælled
mCi Sr-90/km^2	49$\pm$4	63$\pm$2
pCi Sr-90/kg	151$\pm$4	149$\pm$2
Cf. remarks to table 4.2.1.		

Table 4.2.3

Cs-137 in soil collected at the state experimental farms in September 1970 (0-30 cm)

	Tylstrup	Studsgård	Ødum	Askov	St. Jyndevad	Blangstedgård	Tystofte	Virumgård	Abed	Åkirkeby	Mean	SD
mCi Cs-137/km^2	110	88	97	138	137	122	76	107	108	98	108	20
pCi Cs-137/kg	249	249	230	341	287	305	163	252	433	243	275	73
g K/kg	15.5	6.7	18.5	15.0	8.6	15.2	18.8	24.1	14.0	20.3	15.7	5.2

The use of solid-state detectors (Ge(Li)) has made it possible to determine Cs-137 directly by γ-spectroscopy of soil samples. Table 4.2.3 shows the results for the 1970 samples. The Cs-137/Sr-90 mean ratio (0-30 cm) was 1.97 $\pm$ 0.07 (1 SE); in 1969 (0-20 cm) we found 2.00 $\pm$ 0.10 (1 SE) and in 1964 (0-20 cm) 1.75 $\pm$ 0.08 (1 SE). Thus the ratio has increased since 1964. The reason could be that Sr-90 is removed from the soil to a greater extent than is Cs-137, partly by uptake by vegetation partly by wash off from the uppermost soil layers. However, the accumulated amount of Sr-90 in the uppermost 30 cm is in excellent agreement with the expected level (cf. above). Hence we need more information on Cs-137 and Sr-90 in soil before we can be definite about a change in the Cs-137/Sr-90 ratio in soil.

4.3. Sr-90 in Ground Water

As in previous years, ground water was collected in March from the nine locations selected by L. J. Andersen, M. Sc., Geological Survey of Denmark, in 1961.

Fig. 4.3.1 shows the sample locations and table 4.3.1 the results of the Sr-90 analyses (cf. also 5.8.4).

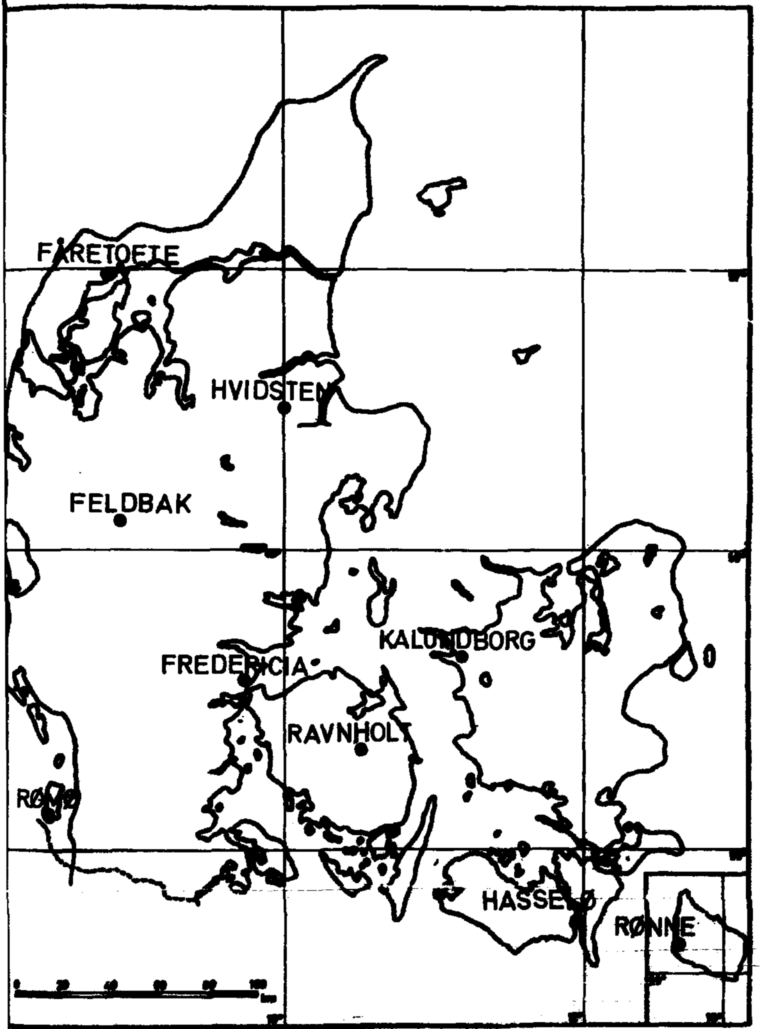

Fig. 4.3.1. Ground-water sampling locations in Denmark.

Table 4.3.1

Sr-90 in ground water collected in March 1970

Location	pCi Sr-90/l	pCi Sr-90/g Ca	g Ca/l
Hvidsten	0.048	0.72	0.065
Feldbak	0.51	21.1	0.024
Rømø	0.016	0.41	0.039
Rønne	0.029	1.33	0.021
Hasselø	0.021	0.11	0.191
Fåretofte	0.0028	0.019	0.147
Kalundborg	0.078	0.75	0.104
Ravnholt	0.011	0.121	0.093
Fredericia	0.005	0.06	0.078
Mean	0.080	-	0.085
Median	0.021	0.41	0.078

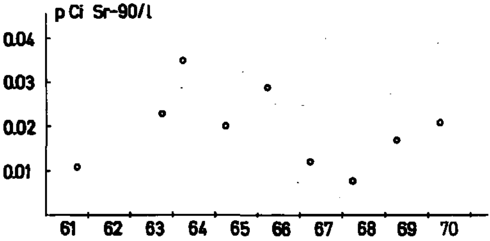

Fig. 4.3.2. Median levels in Danish ground water, 1961-70

The median level of Sr-90 in 1970 was a little higher then in 1967, 1968 and 1969. The highest level is still found at Feldbak. Fig. 4.3.2 shows the median levels in Danish ground water since 1961. It is evident that a maximum occurred in 1964-66. It is too early to decide whether the increase in the median levels observed in recent years is significant.

4.4. Sr-90 in Fresh Water from Danish Streams

In December 1970 a number of water samples was collected from Danish streams. The purpose was to estimate the Sr-90 concentration in

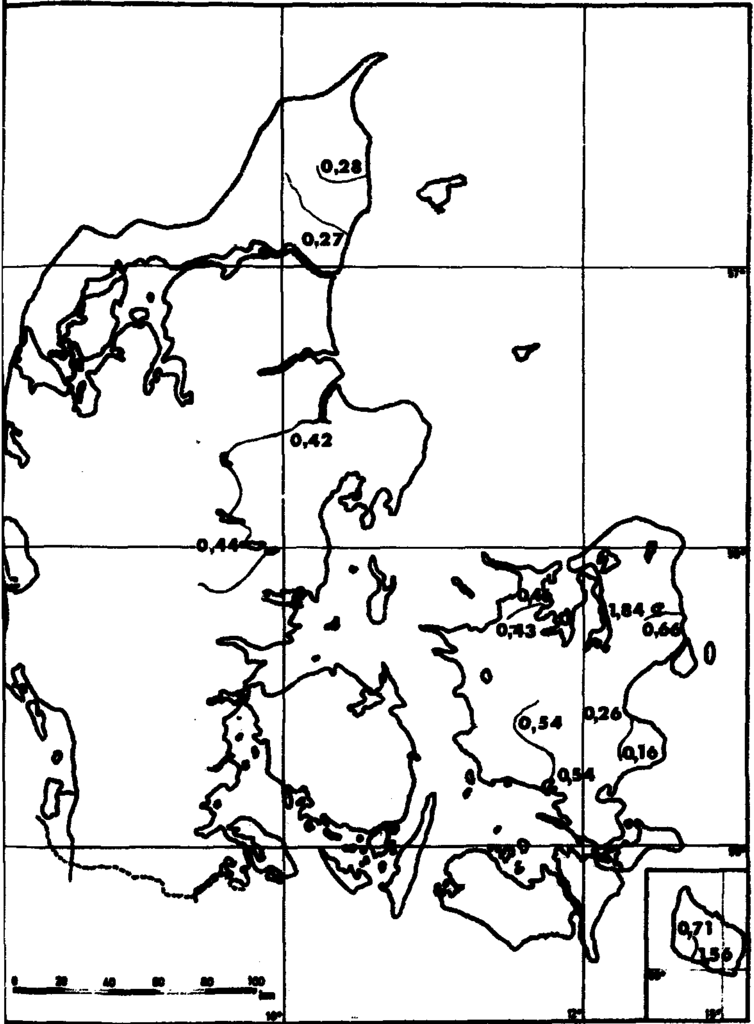

Fig. 4.4. Sr-90 in Danish streams in Dec. 1970 pci/l

Table 4.4

Sr-90 in Danish streams. December 1970

Location		pCi Sr-90/l	g Ca/l	mg Sr/g Ca
Stream	country part			
Sæby å	Sæby, N-Jutland	0.28	0.056	2.1
Vorså	Vorså, N-Jutland	0.27	0.062	2.2
Gudenå	Silkeborg, E-Jutland	0.44	0.042	2.8
Gudenå	Randers, E-Jutland	0.42	0.048	30.0
Asnæs å	*Dragsholm, NW-Zealand*	*0.43*	*0.018*	*3.0*
Asnæs å	Lammefjord, NW-Zealand	0.46	0.014	3.2
Mølleå	Batrup sø, NE-Zealand	1.84	0.073	1.7
Mølleå	Skodsborg, NE-Zealand	0.66	0.080	3.2
Tryggeværldeå	Karise, SE-Zealand	0.16	0.144	7.5
Tryggeværldeå	Køge, SE-Zealand	0.26	0.150	3.5
Suså	Skibby, SW-Zealand	0.54	0.104	4.6
Suså	Næstved, SW-Zealand	0.54	0.114	3.5
Læså	Almindingen, Bornholm	0.71	0.048	1.7
Læså	Boderne, Bornholm	1.57	0.067	2.0

the fresh water supplied to the inner Danish waters. The samples were collected from stream sources and outfalls. Table 4.4 shows that it was not possible to find any systematic difference between source and outfall.

The mean level in the measured samples was 0.61 pCi Sr-90/l (1 SE: 0.13). The median level was 0.45 pCi Sr-90/l. The fresh water samples thus generally showed lower Sr-90 levels than did precipitation (cf. 4.1) and probably lower than surface sea water (cf. 7).

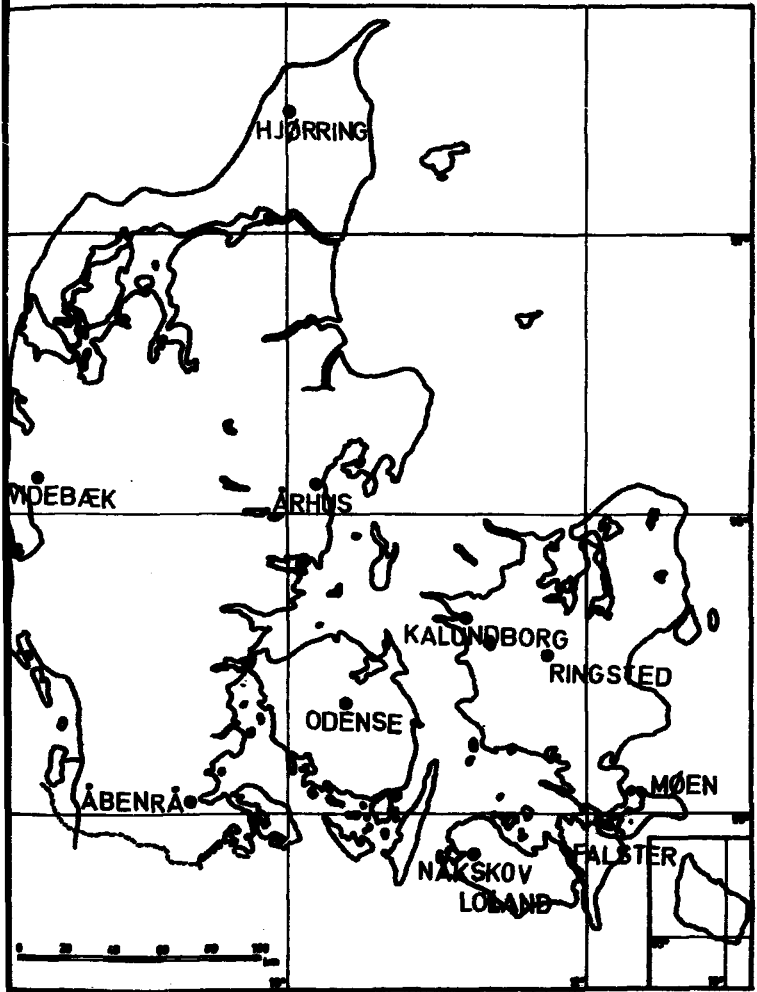

Fig. 5.1.1. Dried-milk factories in Denmark.

5. RADIOSTRONTIUM AND RADIOCAESIUM IN DANISH FOOD IN 1970

5.1. Sr-90 and Cs-137 in Dried Milk from the Entire Country

As in the previous years, monthly samples of dried milk were collected from seven locations in Denmark (cf. fig. 5.1.1) and analysed for Sr-90 and Cs-137.

Table 5.1.1 shows the results of the Sr-90 determinations and table

Table 5.1.1

pCi Sr-90/g Ca in Danish dried milk in 1970

Month	Hjørring	Århus	Videbæk	Åbenrå	Odense	Ringsted	Lolland-Falster Møn	Mean
Jan.	8.4	6.7	10.2	(8.7)	6.1	4.8	3.2	(7.2)
Feb.	8.6	9.1	11.3	7.2	6.2	2.5	4.2	7.0
Mar.	7.4	9.8	13.6	12.1	5.2	2.9	4.3	7.9
Apr.	8.4	4.6	9.5	9.4	6.7	4.4	3.4	6.6
May	8.0	7.9	6.5	9.9	9.2	6.8	3.4	7.6
June	12.5	7.1	10.3	7.1	8.6	2.5	4.4	7.5
July	12.7	7.5	9.8	8.0	5.1	5.8	3.6	7.5
Aug.	12.4	6.9	7.6	7.1	5.4	3.6	2.9	6.6
Sep.	9.4	5.9	11.1	10.1	5.3	4.4	4.4	7.2
Oct.	7.6	7.6	10.7	(8.9)	6.0	5.3	4.0	(7.1)
Nov.	8.6	8.8	11.1	(13.1)	5.5	7.7	4.9	(8.1)
Dec.	6.5	7.2	11.3	(9.6)	6.5	6.1	4.6	(7.7)
Mean	9.4	7.6	10.2	(9.0)	6.3	4.9	3.9	7.3

Figures in brackets were calculated by VAR 3[12]. The error term is the S.E. of the mean. As 1 litre of milk contai 1.2 g Ca, the mean Sr-90 content in Danish milk produced in 1970 was 8.8 pCi/l.

Table 5.1.2

Analysis of variance of ln pCi Sr-90/g Ca in dried milk in 1970
(from table 5.1.1)

Variation	SSD	f	s^2	v^2	P
Betw. locations	4.1451	6	1.5635	25.97	>99.95 %
Betw. months	0.4110	11	0.0374	0.62	-
Remainder	3.7321	62	0.0602		-
η = 0.25					

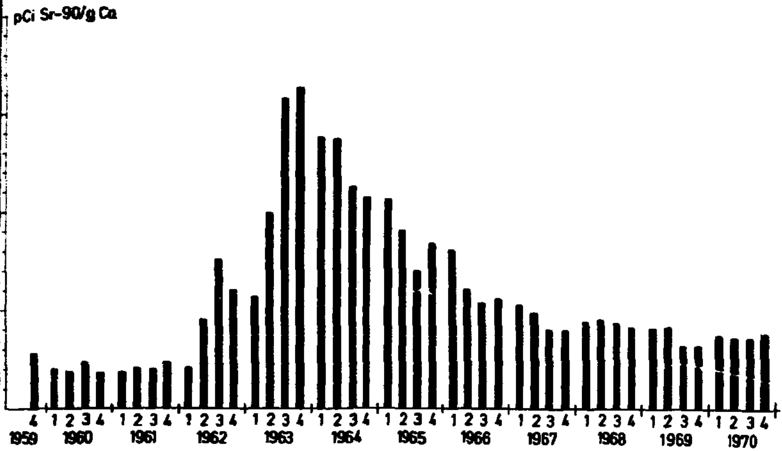

Fig. 5.1.2. Sr-90 in dried milk, 1959-70

Table 5.1.3

pCi Cs-137/g K in Danish dried milk in 1970

Month	Hjørring	Århus	Videbæk	Åbenrå	Odense	Ringsted	Lolland-Falster Møn	Mean
Jan.	6.5	6.8	6.6	(6.1)	3.1	3.0	6.4	(5.5)
Feb.	8.8	4.8	8.0	4.1	4.0	3.3	4.4	5.3
Mar.	6.1	5.2	7.8	6.8	4.4	2.7	4.1	5.3
Apr.	6.9	6.6	10.4	6.6	4.7	4.6	3.7	6.2
May	11.1	8.6	8.8	8.0	6.3	3.8	5.1	7.4
June	11.5	8.6	12.6	11.0	6.7	6.6	4.5	8.8
July	19.4	14.9	22.6	9.8	14.6	9.3	6.4	13.9
Aug.	17.7	17.5	20.6	20.5	8.8	6.3	4.2	13.6
Sep.	20.8	10.9	18.0	22.0	8.9	6.3	5.8	13.2
Oct.	18.7	7.8	14.8	(8.2)	4.5	2.4	4.5	(8.7)
Nov.	7.6	7.2	9.4	(6.4)	5.2	(3.3)	2.6	(6.0)
Dec.	9.3	5.2	15.4	(7.1)	3.9	4.3	3.6	(7.0)
Mean	12.0	8.7	12.9	(9.7)	6.2	4.7	4.6	8.4

As 1 litre of milk contains approx. 1.66 g K, the mean Cs-137 content in Danish milk produced in 1970 was estimated at 14 pCi/l.

Table 5.1.4

Analysis of variance of ln M. U. in Danish dried milk in 1970
(from table 5.1.3)

Variation	SSD	f	s^2	v^2	P
Betw. locations	11.7735	6	1.9623	28.15	>99.95 %
Betw. months	8.6005	11	0.7819	11.21	>99.95 %
Remainder	4.2491	61	0.0697		
η = 0.26					

5.1.2 the analysis of variance of the results. The maximum of the year was reached by 8.1 S.U. in November. The S.U. mean level in 1970 was 7.3 pCi Sr-90/g Ca or approx. equal to the 1969 mean.

As in the previous years, the milk from eastern Denmark shows significantly lower levels than that from Jutland.

Table 5.1.3 shows the results of the Cs-137 determinations and table 5.1.4 the analysis of variance of the results. As in the previous years, the maximum level of Cs-137 (13.9 M.U., approx. 85% of the maximum of 1969) was found in milk from the summer (July). The M.U. mean level in 1970 was 8.4 pCi Cs-137/g K or approx. 85% of the Cs-137 mean content found in 1969.

Figs. 5.1.2 and 5.1.3 show the quarterly S.U. and M.U. values since October-December 1959 (cf. also Appendix C).

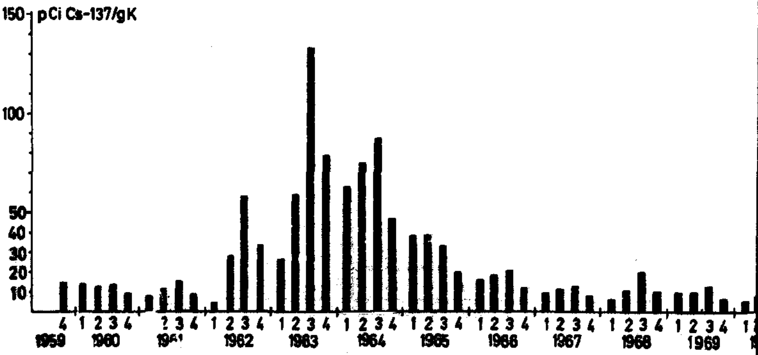

Fig. 5.1.3. Cs-137 in dried milk, 1959-70

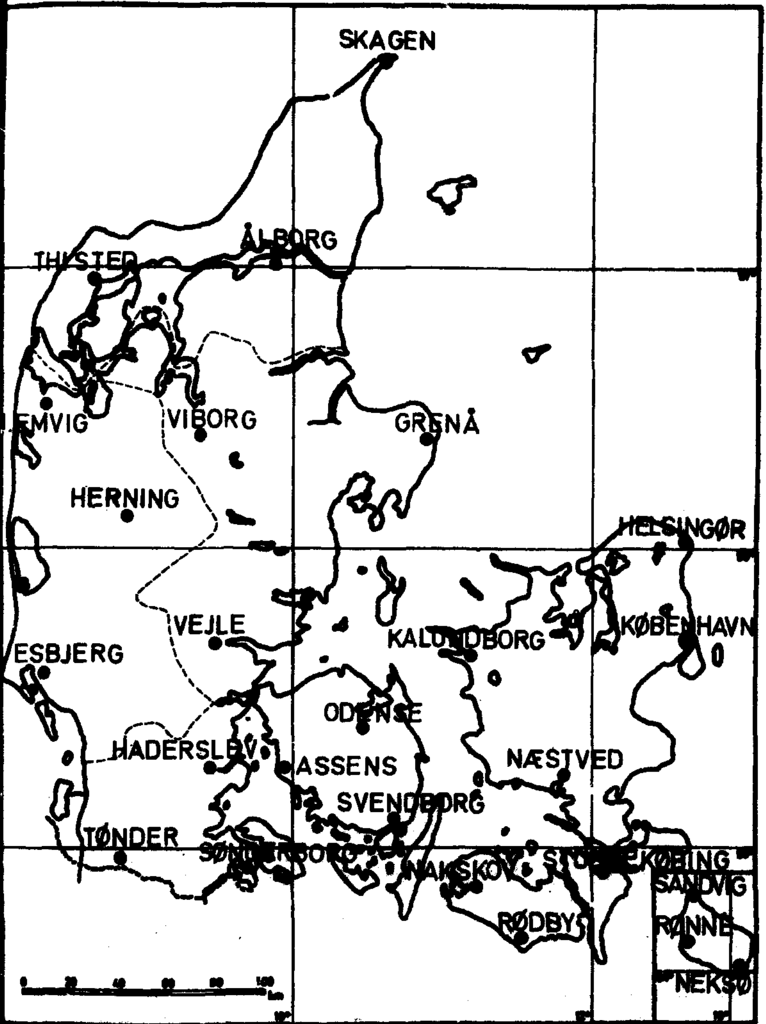

Fig. 5.2.1. Sample locations for fresh milk, bread and total diet (A-towns).

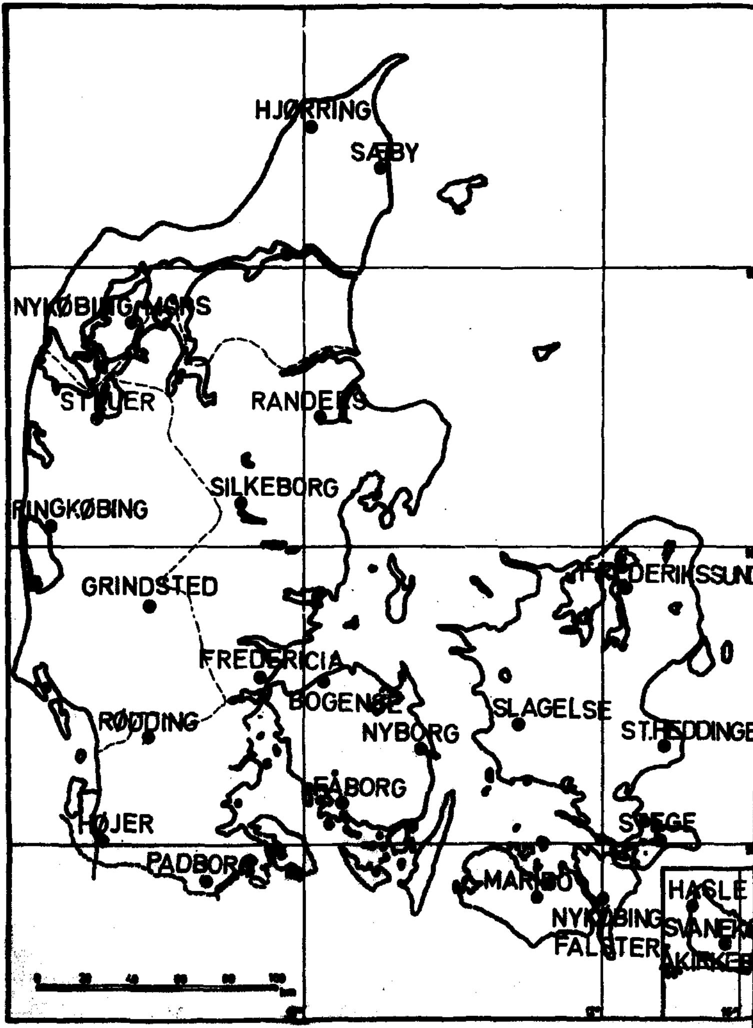

Fig. 5.2.2. Sample locations for fresh milk, bread and total diet (B-towns).

5.2. Sr-90 and Cs-137 in Fresh Milk from the Entire Country

The samples of fresh milk were collected in the eight zones and in Copenhagen as in previous years (cf. figs. 5.2.1 and 5.2.2) in connection with the bread and total-diet collection (cf. 5.7).

Table 5.2.1 shows the results of the determinations of radiostrontium and Cs-137 in consumer milk.

The production-weighted means for Sr-90 and Cs-137 in Danish consumer milk in 1970 were 7.8 S.U. (~9.4 pCi Sr-90/l) and 6.5 M.U. or 10.3 pCi Cs-137/l respectively.

As previously it seems reasonable to regard the mean of the levels found in June and December as representative of the annual production-weighted mean, as the mean for these two months calculated from the dried-milk data (cf. tables 5.1.1 and 5.1.2) yielded a reasonable estimate of the annual mean for dried milk.

In the figures in table 5.2.1 are weighted with respect to the population, the country means become 7.8 S.U. and 9.6 pCi Cs-137/l, i.e. almost the same as the production-weighted means.

Table 5.2.1

Sr-90 and Cs-137 in fresh milk in 1970

Zone	June 1970			December 1970		
	pCi Sr-90/g Ca	pCi Cs-137/g K	pCi Cs-137/l	pCi Sr-90/g Ca	pCi Cs-137/g K	pCi Cs-137/l
N. Jutland	7.8	9.1	14.2	7.7	8.4	12.8
E. Jutland	7.9	6.4	9.8	7.5	4.1	6.5
W. Jutland	6.9	7.6	11.9	10.7	7.2	11.3
S. Jutland	7.7	8.8	14.0	11.5	6.8	10.6
Funen	3.3	6.1	9.6	5.3	3.1	4.9
Sealand	7.4	6.8	11.2	9.4	4.2	6.9
: Lolland-Falster	4.4	5.0	7.3	4.7	3.9	6.3
I: Bornholm	5.1	6.2	9.4	6.0	2.2	3.4
an	6.3	7.0	10.9	7.9	5.0	7.8
penhagen	8.5	5.8	8.9	8.7	6.0	9.1
pulation-weighted mean	7.3	6.8	10.6	8.4	5.5	8.6
oduction-weighted mean	7.1	7.4	11.6	8.5	5.7	9.0

5.3. Sr-90 and Cs-137 in Grain from the Entire Country

As in the previous years, grain samples were obtained from ten State experimental farms (cf. fig. 4.1.1). Virumgård was replaced by Ledreborg in 1969. Sr-90 was determined as previously (Risö Report No. 63[1]), and Cs-137 was measured on ashed samples by γ-spectrometry on a Ge-detector.

Table 5.3.1

Sr-90 in Danish grain in 1970

	Rye		Barley		Wheat		Oats	
	pCi Sr-90/kg	S.U.	pCi Sr-90/kg	S.U.	pCi Sr-90/kg	S.U.	pCi Sr-90/kg	S.U.
Tylstrup	37	107	53±4	119±10	50	92	74	91
Studsgård	46	135	82	136	w:58 s:107	w:144 s:194	79	82
Ødum	15±3	45±3	23	56	w:20 s:24	w:55 s:61	35	33
Askov	31	83	42	67	w:58 s:69	w:155 s:157	40	46
St. Jyndevad	50	156	56	171	-	-	88	77
Blangstedgård	29	75	23	45	30	69	77	61
Tystofte	17	38	w:18 s:20	w:31 s:39	w:21 s:20	w:53 s:50	32	31
Ledreborg	33±1	85±4	32±5	58±12	w:32 s:34±1	w:89 s:85±2	32±1	31±[illegible]
Abed	-	-	25	49	23	60	31±3	31±[illegible]
Åkirkeby	21	58	-	-	w:16 s:39	w:59 s:78	66	68
Mean	31	87	37	77	40	93	55	55

w: winter variety, s: spring variety. The error term is the S.E. of the mean double determinations

Table 5.3.2

Analysis of variance of ln S.U. in grain in 1970
(from table 5.3.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	2.6751	3	0.8917	12.37	> 99.95%
Betw. locations	8.5172	9	0.9464	13.13	> 99.95%
Spec. x locations	1.7305	24	0.0721	4.07	> 99.5%
Remainder	0.2483	14	0.0177		

η = 0.13

The main effects were tested against the interaction

Table 5.3.1 shows the measurements of strontium-90 in grain in 1970. According to Appendix B, approx. 2/3 of all rye in Denmark is grown in Jutland and 1/3 in the eastern part of the country. As regards wheat, 3/4 is produced in eastern Denmark and 1/4 in Jutland. In the calculation of the means in tables 5.3.1 and 5.3.4 Jutland is represented by five rye figures and seven wheat figures, while eastern Denmark contributes eight wheat figures and four rye figures. Thus the means in tables 5.3.1-5.3.4 for rye are a little lower and those for wheat are probably a little higher than the production-weighted means for the country. Table 5.3.2 gives the analysis of variance of the S.U. figures and table 5.3.3 that of the pCi Sr-90/kg grain figures.

Table 5.3.3

Analysis of variance of ln pCi Sr-90/kg grain in 1970 (from table 5.3.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	1.8187	3	0.6062	8.30	⟩99.9%
Betw. locations	8.3832	9	0.9315	12.76	⟩99.95%
Loc. x species	1.7530	24	0.0730	1.29	-
Remainder	0.7914	14	0.0565		
η = 0.24					

Table 5.3.4

Cs-137 in Danish grain in 1970

	Rye		Barley		Wheat		Oats	
	pCiCs-137/kg	M.U.	pCiCs-137/kg	M.U.	pCiCs-137/kg	M.U.	pCiCs-137/kg	M.U.
Tylstrup	76	20	62	13	32	8	43	13
Studsgård	w:129	w:27	68	14	w:80 s:100	w:19 s:28	77	27
Ødum	71	25	64	16	w:58 s:65	w:18 s:19	70	17
Askov	w:101	w:23	79	23	w:80 s:74	w:24 s:22	55	17
St. Jyndevad	88	23	34	11	-	-	78	24
Blangstedgård	59	16	51	11	w:31	w:10	61	16
Tystofte	82	23	w:44 s:55	w:13 s:12	w:46 s:63	w:15 s:18	61	20
Ledreborg	66	16	47	12	w:42 s:49	w:13 s:14	74	21
Abed	-	-	52	14	w:47	w:13	16	4
Åkirkeby	89	21			w:40 s:52	w:10 s:15	27	7
Mean	83	22	56	14	57	16	56	17

w: winter variety, s: spring variety

Table 5.3.5

Analysis of variance of ln pCi Cs-137/g K grain in 1970
(from table 5.3.4)

Variation	SSD	f	s^2	v^2	P
Betw. species	0.9408	3	0.3136	2.88	〉90%
Betw. locations	2.7331	9	0.3037	2.79	〉97.5%
Spec. x locations	2.6158	24	0.1090	4.04	〉97.5%
Remainder	0.1890	7	0.0270		
η = 0.16. Main effects were tested against interaction.					

Table 5.3.6

Analysis of variance of ln pCi Cs-137/kg grain in 1970
(from table 5.3.4)

Variation	SSD	f	s^2	v^2	P
Betw. species	1.2546	3	0.4182	3.89	〉97.5%
Betw. locations	2.4626	9	0.2736	2.55	〉95%
Spec. x locations	2.5792	24	0.1075	4.70	〉97.5%
Remainder	0.1602	7	0.0229		
η = 0.15 Main effects were tested against interaction					

Table 5.3.2 shows that the variation in S.U. between species was significant. Wheat showed the highest S.U. levels and oats the lowest. The pCi Sr-90/kg figures also show a significant difference between species. (Oats 〉 rye).

As in previous years, the variation with location was highly significant; the mean pCi Sr-90/kg level for grain from Jutland was approx. 1.7 times that in eastern Denmark.

Table 5.3.4 shows the measurements of Cs-137 in grain in 1970, table 5.3.5 the anrlysis of variance of the M.U. figures and table 5.3.6 the analysis of variance of the pCi Cs-137/kg grain figures. The variation between locations was significant. The Cs-137 content in grain from Jutland was on the average approx. 1.3 (pCi/kg figures) times as high as the grain level in eastern Denmark. The variation between species was probably significant. Rye contained as previously more Cs-137 than did the other grain species.

If the S. U. levels in grain from the harvest of 1970 are compared with the levels from 1969[1], we find the 1970 figures to be greater by a factor of approx. 1.3.

The Cs-137 content in grain from the 1970 harvest was on the average greater by a factor of 1.7 than that in 1969. The fall-out rate in May-August 1970 was 1.5 times that in May-August 1969. (The period May-August was selected because experiments have shown[10] that the contamination of grain with Cs-137 originates in the period from before the emergence of the ears until harvest). This observation is in reasonable agreement with that of the previous years and fits the hypothesis that the Cs-137 level in grain depends mainly upon the fall-out rate.

In Appendix C is shown a comparison between observed and predicted Sr-90 and Cs-137 levels in 1970. It is evident that the predicted levels for grain were higher than those observed. The observed values were for Sr-90 two thirds of those predicted and for Cs-137 three fourths.

The mean ratio between pCi Cs-137/kg rye and pCi Sr-90/kg rye was 2.7, while the Cs-137/Sr-90 ratio for barley, wheat and oats was 1.3. This is in agreement with earlier observations and with the theory that rye depends more on direct contamination than the other cereals, for which the soil uptake of Sr-90 now plays a dominant role.

Table 5.3.7

mg Sr/g Ca in grain collected in 1970

	Rye		Barley		Wheat		Oats
	w	s	w	s	w	s	s
Tylstrup	3.2			3.3	2.2		2.3
Studsgård	2.8			4.7	2.5	3.7	2.4
Ødum	2.2			2.4	4.7	3.9	3.0
Askov	3.0			2.2	3.8	1.4	3.1
St. Jyndevad	2.2			2.1			1.4
Blangstedgård	3.3			2.9	4.3		
Tystofte	2.5		1.9	3.0	2.3	2.1	1.2
Ledreborg	2.1			1.8	1.6	2.6	1.0
Abed				4.1	4.0		3.2
Åkirkeby	2.0				2.6	2.1	1.6

Table 5.3.8

Analysis of variance of ln mg Sr/g Ca in grain in 1970
(from table 5.3.7)

Variation	SSD	f	s^2	v^2	P
Betw. species	0.6274	3	0.2091	3.25	> 95%
Betw. locations	2.8438	9	0.3160	4.91	> 99.9%
Spec. x locations	1.4781	23	0.0643	0.53	-
Remainder	0.8482	7	0.1212		
η = 0.36					

Table 5.3.7 shows the stable-strontium content in grain in relation to the calcium content, and table 5.3.8 is an analysis of variance of the figures. As previously[1], wheat contained more stable strontium per g Ca than the other species, and the station in Jutland showed generally higher figures than the eastern locations.

5.4. Sr-90 and Cs-137 in Bread from the Entire Country

In 1970, samples of white bread (75% extraction) and dark rye bread (100% extraction) were collected as previously all over the country in June and December (in both A and B towns, cf. figs. 5.2.1 and 5.2.2). The samples were combined into eight zone samples and a sample from Copenhagen, and Sr-90 and Cs-137 were determined. The Cs-137 determinations were carried out on dried samples of rye bread and on the ash of white bread by γ-spectroscopy.

Tables 5.4.1 and 5.4.2 show the results. In figs. 5.4.1 and 5.4.2 a comparison with grain levels is made for the years 1962-1970. It is assumed that the bread consumed in the first nine months of the i^{th} year has been made of grain from the harvest in the $(i-1)^{th}$ year, while the bread consumed in the last three months has come from the harvest in the i^{th} year. Further it is assumed that 1 kg flour yields approx. 1.35 kg bread[11] and that wheat flour of 75% extraction contains 20% of the Sr-90 and 50% of the Cs-137 found in wheat grain[1].

Figs. 5.4.1 and 5.4.2 show that the Sr-90 and Cs-137 levels in bread were in reasonable agreement with those in grain according to the above-mentioned model.

Table 5.4.1

Sr-90 in Danish bread in 1970

Zone		June				December			
		White bread		Rye bread		White bread		Rye bread	
		pCi/kg	S. U.	pCi/kg	S. U.	pCi/kg	S. U.	pCi/kg	S. U.
I:	N. Jutland	7.8	4.0	26±1	8.2±0.4	4.1	2.3	31	10.7
II:	E. Jutland	5.4	2.9	35	10.5	4.4	2.2	41	12.4
III:	W. Jutland	6.5	3.9	34±1	9.1±0.9	4.1	1.9	44	14.4
IV:	S. Jutland	6.9	3.6	30±3	9.6±2.6	6.2	3.6	35	11.6
V:	Funen	5.0	2.4	22±0	5.0±0.2	3.8	1.8	24	8.8
VI:	Sealand	5.1	1.8	15±3	4.6±0.6	6.8	3.6	22	4.8
VII:	Lolland-Falster	7.9	3.4	16	5.2	5.4	2.7	21	7.0
VIII:	Bornholm	4.7	1.9	17±1	5.4±0.1	7.2	2.8	18	6.4
Mean		6.2	3.0	24	7.3	5.3	2.6	30	9.5
Copenhagen		4.0	5.0	18±2	6.4±0.6	4.6	2.3	20	7.2
Population-weighted mean		5.4	3.6	24	7.4	4.8	2.5	29	9.3

Table 5.4.2

Cs-137 in Danish bread in 1970

Zone		June				December			
		White bread		Rye bread		White bread		Rye bread	
		pCi/kg	M. U.	pCi/kg	M. U.	pCi/kg	M. U.	pCi/kg	M. U.
I:	N. Jutland	10.1	6.8	40	13	10.1	7.1	50	17
II:	E. Jutland	9.6	6.6	46	13	14.2	10.6	87	32
III:	W. Jutland	8.9	6.4	50	15	14.8	10.5	58	19
IV:	S. Jutland	11.7	8.3	49	13	27.2	20.8	57	22
V:	Funen	8.3	5.7	30	9	15.2	11.0	29	11
VI:	Sealand	9.5	6.7	31	10	13.8	9.7	48	18
VII:	Lolland-Falster	11.9	7.3	34	11	12.2	8.7	40	15
VIII:	Bornholm	9.1	6.9	38	9	10.4	7.4	50	14
Mean		9.9	6.8	40	12	14.7	10.7	52	19
Copenhagen		10.9	8.1	40	12	10.2	8.7	32	10
Population-weighted mean		10.0	7.1	40	12	13.2	10.0	50	17

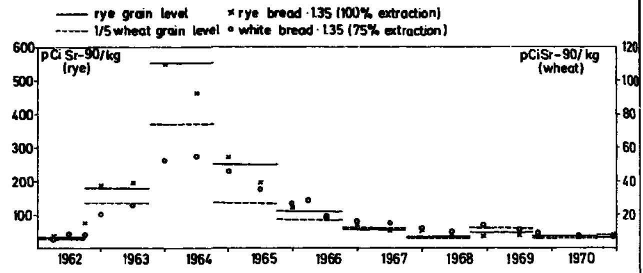

Fig. 5.4.1. Comparison of Sr-90 levels in bread and grain, 1962-70

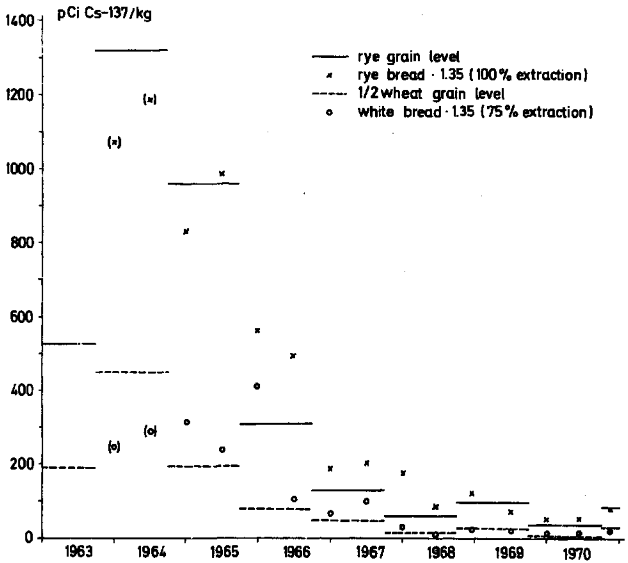

Fig. 5.4.2. Comparison of Cs-137 levels in bread and grain, 1962-70

On comparison of the bread levels in Jutland with those in eastern Denmark it appeared that the Sr-90 and Cs-137 levels in rye bread in Jutland were approx. 1.6 times those in eastern Denmark, whereas Sr-90 and Cs-137 in white bread were nearly equal all over the country. This shows as also observed the other years that it is not necessarily local-grown grain that is used for the bread production (cf. 5.3).

5.5. Sr-90 and Cs-137 in Potatoes from the Entire Country

The samples of potatoes were collected in September from nine of the State experimental farms (cf. fig. 4.1.1) and analysed for Sr-90 and Cs-137 (γ-spectroscopy of bulked samples of the ash).

Table 5.5.1 shows the Sr-90 and Cs-137 contents in potatoes. The mean contents for the country were 3.3 pCi Sr-90/kg or 83 S.U. and 12.4 pCi Cs-137/kg or 2.6 M.U.

The mean of the Cs-137/Sr-90 ratios (pCi/kg figures) was 3.8 (in 1969: 1.8, in 1968: 2.6, in 1967: 2.1, in 1966: 2.6, in 1965: 6, and in 1964: 9).

Table 5.5.1

Sr-90 and Cs-137 in Danish potatoes in 1970

	pCi Sr-90/kg	S.U.	pCi Cs-137/kg	M.U.
Tylstrup	2.6	108		
Studsgård	4.1±0.3	95±8		
Ødum	2.3±0.0	69±2	16.4	3.3
Askov	4.1±0.1	160±6		
St. Jyndevad	2.2±0.2	67±10		
Blangstedgård	2.1±0.3	25±4		
Tystofte	3.0	57		
Ledreborg	3.9±0.2	67±9	8.3	2.0
Abed	3.8±0.3	46±4		
Åkirkeby	4.9	134		
Mean	3.3	83	12.4	2.6

The error term is the S.E. of double determinations.

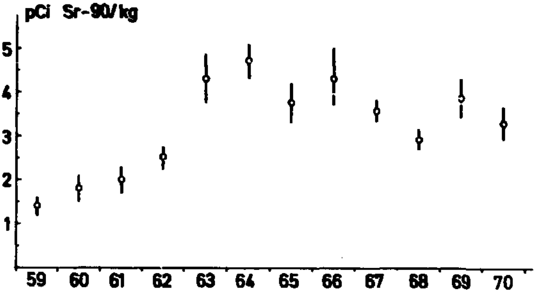

Fig. 5.5. Sr-90 levels in Danish potatoes 1959-70 (1 S.E. indicated)

5.6. Sr-90 and Cs-137 in Vegetables and Fruits from the Entire Country

In 1970 as in previous years, vegetables and fruits were collected in September and December from eight greater provincial towns, one in each of the eight zones, and from Copenhagen.

Carrots and onions were collected in September, cabbages and apples in December, and a few samples of peas, strawberries and gooseberries were collected in June-July.

Table 5.6.1

Sr-90 in vegetables and fruits in 1970

Zone	Cabbage		Carrot		Onion		Peas		Apple		Strawberri
	pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg
I: N-Jutland	8±2	16±1	28	83	2±1	6±1	(2)	(12)	1.3	39	(8)
II: E-Jutland	13±4	31±12	8±1	33±6	32	63	5	22	1.6	39	9
III: W-Jutland	16±2	33±4	30	102	22	63	(5)	(20)	1.6	25	(17)
IV: S-Jutland	15±8	27±13	30	86	11	36	(4)	(23)	1.3	25	(13)
V: Funen	16±4	29±14	17	62	18	57	5	24	3.7	61	15
VI: Sealand	13±3	18±4	8±1	23±3	14	35	3	16	0.9	20	16
VII: Lolland-Falster	8±1	17±0	16	46	13	29	(3)	(14)	0.8	16	5
VIII: Bornholm	9±1	19±1	19	47	2±1	8±1	(2)	(13)	1.4	24	7
Mean	12	24	19	59	14	46	(9)	(19)	1.6	31	(11)
Copenhagen	6	13	8	20	13	48	(3)	(16)	1.3	37	7
Population-weighted mean	11	21	14	46	16	47	4	20	1.5	35	11

Values in brackets were calculated from VAR 3

The error term is the S.E. of the mean of double determinations

Table 5.6.2

Analysis of variance of ln pCi Sr-90/kg in vegetables and fruits in 1970
(from table 5.6.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	32.2365	5	6.4473	30.00	$\rangle$ 99.95%
Betw. locations	7.0856	7	1.0122	2.02	-
Spec. x locations	13.5151	27	0.5006	2.33	$\rangle$ 95%
Remainder	2.5790	12	0.2149		
η = 0.48					

Table 5.6.3

Analysis of variance of ln S.U. in vegetables and fruits in 1970
(from table 5.6.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	4.6809	5	0.9362	2.50	-
Betw. locations	5.2079	7	0.7440	1.99	-
Spec. x locations	10.0928	27	0.3738	2.56	$\rangle$ 95%
Remainder	1.7520	12	0.1460		
η = 0.40					

Table 5.6.4

Cs-137 in vegetables and fruits in 1970

	Cabbage	Carrot	Onion	Apple	Pea	Strawberry	Gooseberry
pCi/kg	2.7±0.9	6.6	0	13.7	8.2±0.9	2.3	3.4
pCi/g K	0.9±0.3	2.1	0	9.2	2.6±0.2	1.4	1.9
The error term is the S.E. of the mean							

The γ-measurements were performed on bulked ash samples representing the entire country (cf. table 5.6.4). Tables 5.6.1 - 5.6.3 show the results and the analysis of variance of the Sr-90 determinations.

Table 5.6.5

Calculated Sr-90 and Cs-137 mean levels in vegetables in 1970

Daily intake in g	Species	pCi Sr-90 per kg	S. U.	pCi Cs-137 per kg	M. U.
50	Leafy vegetables (cabbage)	11	21	2.7	0.9
30	Root vegetables (carrot, onion)	15	46	2.8	1.0
40	Pea (and bean)	4	19	8.2	2.6
120	Vegetable total	10	27	4.6	1.5

Pea and bean were calculated as the mean of 3 pea samples collected in Jutland, Zealand and Funen.

The variations between species were highly significant (pCi Sr-90 figures). The highest Sr-90 levels (pCi/kg) were found in onion, the lowest in apple.

Table 5.6.5 shows a calculation of the mean contents of Sr-90 and Cs-137 in Danish vegetables collected in 1970. The levels were the population-weighted means calculated in tables 5.6.1 - 5.6.4.

The 1970 levels in Danish fruit were calculated from apple and from strawberry. Apples got a weight factor of 85 and strawberries one of 15, and the mean levels in Danish fruit were thus 2.9 pCi Sr-90/kg and 12 Cs-137/kg.

The 1970 Sr-90 and Cs-137 levels in vegetables and fruits were a little lower than the 1969 levels, (cf. also Appendix C).

5.7. Sr-90 and Cs-137 in Total Diet from the Entire Country

In 1970 total-food samples representing an average Danish diet according to Hoff-Jørgensen (cf. Appendix B in Risö Report No. 63[1]) where collected according to the principles followed in 1961-1969. As previously, two groups of towns (A and B, cf. figs. 5.2.1 and 5.2.2) supplied the samples.

Tables 5.7.1 and 5.7.2 show the results. As in the previous years, the variation between locations was significant. The S.U. levels in the total diet were approx. 40% higher in Jutland than in eastern Denmark.

Fig. 5.7.1 shows the zone mean levels (not population weighted) of S.U. in total diet since May 1961. Fig. 5.7.2 shows the daily Cs-137 intake since June 1963.

Table 5.7.1

Sr-90 and Cs-137 in total Danish diet collected in June 1970

Zone	pCi Sr-90/g Ca	pCi Sr-90/day	g Ca/day	pCi Cs-137/g K	pCi Cs-137/day
I: N-Jutland	9.7±1.1	17.4±0.3	1.82±0.19	9.1±1.9	34±9
II: E-Jutland	9.2±1.6	16.2±4.0	1.76±0.13	8.2±0.4	32±3
III: W-Jutland	8.7±1.7	14.2±4.7	1.59±0.23	8.8±2.2	34±10
IV: S-Jutland	10.9±1.8	17.8±3.0	1.64±0.01	9.5±1.4	36±5
V: Funen	8.7±1.4	16.6±3.5	1.88±0.10	5.2±0.1	21±1
VI: Sealand	8.3	14.5	1.75	5.2±0.6	21±2
VII: Lolland-Falster	4.8±1.6	7.6±1.6	1.58±0.01	7.3±1.0	28±4
VIII: Bornholm	7.8±0.2	14.9±1.8	1.90±0.19	5.8±0.9	22±3
Mean	8.5	14.9	1.74	7.4	29
Copenhagen	9.6±1.3	17.7±0.9	1.85±0.04	11.5	40
Population-weighted mean	9.1	16.1	1.77	8.6	32
Relative error due to sampling and analysis	22%	26%	11%	24%	30%

Table 5.7.2

Sr-90 and Cs-137 in Danish total diet collected in December 1970

Zone	pCi Sr-90/g Ca	pCi Sr-90/day	g Ca/day	pCi Cs-137/g K	pCi Cs-137/day
I: N-Jutland	7.8±1.0	12.9±0.9	1.67±0.10	10.4±0.6	33±0
II: E-Jutland	8.4±1.3	15.0±0.9	1.80±0.16	12.5±0.0	41±4
III: W-Jutland	9.4±0.4	16.0±0.8	1.72±0.16	12.8±1.7	39±6
IV: S-Jutland	9.6±1.9	16.9±4.5	1.74±0.12	13.2±0.7	46±2
V: Funen	5.5±0.2	10.7±0.7	1.88±0.18	3.0±0.3	11±0
VI: Sealand	7.2±0.3	11.9±1.0	1.66±0.08	6.2±0.2	21±1
VII: Lolland-Falster	6.1±0.2	10.4±0.4	1.70±0.01	7.7±1.6	27±6
VIII: Bornholm	5.6±0.6	11.2±0.5	2.03±0.18	8.0±0.5	27±1
Mean	7.4	13.1	1.77	9.2	31
Copenhagen	6.6±0.8	11.0±1.0	1.66±0.04	7.8	28
Population-weighted mean	7.5	12.6	1.72	9.1	30
Relative error due to sampling and analysis	17%	18%	10%	14%	19%

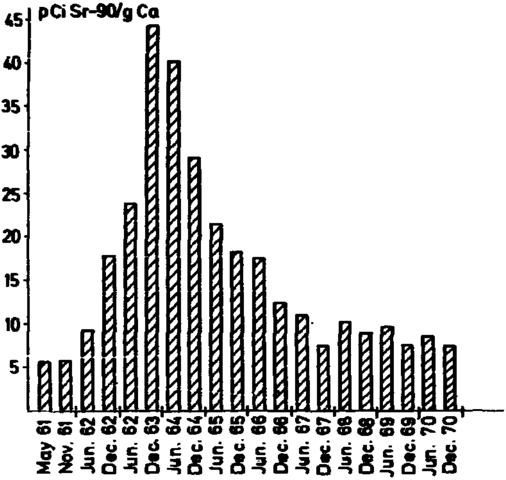

Fig. 5.7.1. pCi Sr-90/g Ca in Danish total diet, 1961-70

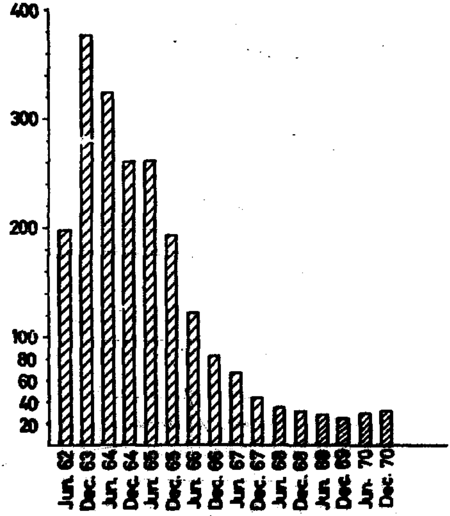

Fig. 5.7.2. pCi Cs-137/day from Danish total diet, 1962-70

The 1970 Sr-90 levels in total diet were almost equal to the 1969 levels, while the Cs-137 levels were approx. 30% greater than the 1969 ones.

From the total-diet sampling it is possible to estimate the mean levels of Sr-90 and Cs-137 in the Danish diet in 1970. For the period January-April 1970 the Sr-90 level in the total diet is assumed to have been equal to that measured in December 1969, Risö Report No. 201[1]. For the period May-September we assume the level to have corresponded to that measured in June 1970. The December 1970 figure is taken to represent the last three months of the year. The population-weighted mean of Sr-90 in total-diet samples was 7.2 pCi Sr-90/g Ca in December 1969. Hence the mean content in the total diet in 1970 was 8.1 pCi Sr-90/g Ca or 14.1 pCi Sr-90/day.

In a similar way the Cs-137 content in the Danish diet in 1970 was estimated to be 30 pCi Cs-137/day or 8.2 pCi Cs-137/g K (cf. also Appendix C).

5.8. Sr-90 and Cs-137 in Miscellaneous Foodstuffs

5.8.1. Sr-90 and Cs-137 in Meat

Pork and beef samples were collected in Copenhagen (cf. figs. 5.2.1 and 5.2.2) in three big shops in May, June, September, and December.

Table 5.8.1

Sr-90 and Cs-137 in pork, beef and veal from Copenhagen in 1970

Species	Unit	May	June	Sep.	Dec.	Mean
Pork	pCi Sr-90/kg	0.6	1.4	0.4	1.2	0.9
	pCi Sr-90/g Ca	5	10	6	8	7
	pCi Cs-137/kg	67	44	28	112	63
	pCi Cs-137/g K	22	14	10	30	19
Beef	pCi Sr-90/kg	1.6	0.9	1.2	2.1	1.4
	pCi Sr-90/g Ca	15	18	18	14	16
	pCi Cs-137/kg	90	22	57	39	52
	pCi Cs-137/g K	37	6	14	12	22
Veal	pCi Sr-90/kg	0.8	1.8	0.8	0.8	1.1
	pCi Sr-90/g Ca	11	10	13	9	11
	pCi Cs-137/kg	111	44	43	70	67
	pCi Cs-137/g K	30	13	11	17	18

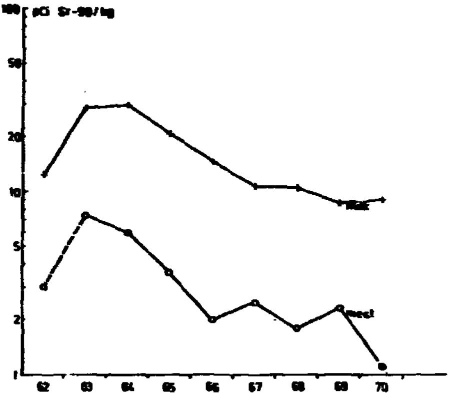

Fig. 5.8.1.1. Sr-90 in Danish milk and meat (2/3 pork and 1/3 beef) 1962-70

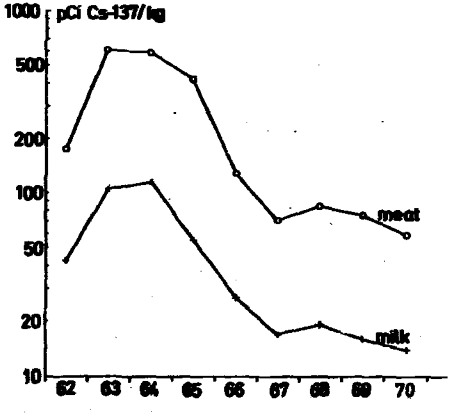

Fig. 5.8.1.2. Cs-137 in Danish milk and meat (2/3 pork and 1/3 beef) 1962-70

Table 5.8.1 shows the results. Figs. 5.8.1.1 and 5.8.1.2 show a comparison between milk and meat levels. The ratio pCi Sr-90/kg meat/pCi Sr-90/l milk was 0.20 (S.E. 0.02), and the corresponding ratio for Cs-137 was 5.1 (S.E. 0.4) for the period 1962-1970. (In these calculations meat consisted of 2/3 pork and 1/3 beef) (cf. also Appendix C).

5.8.2. Sr-90 and Cs-137 in Fish

Fish samples were collected at two fishing harbours, Esbjerg and Skagen in Jutland. Table 5.8.2 shows the results. The levels were lower

Table 5.8.2

Sr-90 and Cs-137 in fish collected in 1970 in Danish waters

Species		Month	pCi Sr-90 per kg	pCi Sr-90 per g Ca	pCi Cs-137 per kg	pCi Cs-137 per g K
Plaice	meat	Dec.	0.32	0.59	16	4
	bone		-	0.26	-	-
Cod	meat	Dec.	0.43	0.68	58	12
	bone		-	0.32	-	-
Herring	meat	Dec.	0.23	0.44	38	9
	bone		-		-	-
Mean	meat		0.33	0.57	37	8
	bone		-	0.3	-	-

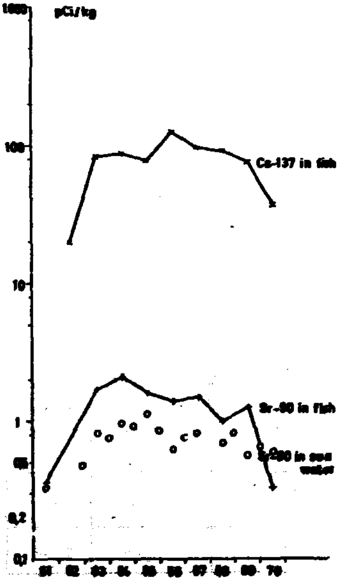

Fig. 5.8.2. Sr-90 and Cs-137 in Danish fish compared with Sr-90 in sea water 1961-70

than the 1969, 1968 and 1967 concentrations, perhaps because the fish were from the North sea and not from inner Danish waters as previously.

Fig. 5.8.2 shows a correlation between Sr-90 in surface sea water an Sr-90 in fish meat. The Sr-90 concentration in fish was approx. two times that in sea water.

The figure further shows that the Cs-137 concentration in fish was approx. a hundred times the Sr-90 level in sea water. The Cs-137/Sr-90 ratio in sea water is 1.6 (S.E. 0.1)[16], hence the concentration factor for fish from sea water becomes 65.

5.8.3. Sr-90 in Drinking Water

Along with the total-diet samples, 10 l of drinking water was collected in June in each of the 48 towns (cf. figs. 5.2.1 and 5.2.2). The 10 l samples were bulked into eight zone samples, each comprising 60 l of water. Furthermore, 3 · 20 l of water were collected from three different parts of Copenhagen and combined to a 60 l sample. The samples were analysed, by the method used for ground water, for Sr-90, stable strontium and calcium.

Table 5.8.3 shows the results.

Table 5.8.3

Sr-90 in Danish drinking water in 1970

Zone		pCi Sr-90/l	June g Ca/l	mg Sr/g Ca
I:	N-Jutland	0.022	0.074	4.3
II:	E-Jutland	0.006	0.075	5.9
III:	W-Jutland	B 0.004	0.056	2.3
IV:	S-Jutland	A 0.002	0.099	1.8
V:	Funen	A 0.002	0.093	7.8
VI:	Zealand	B 0.002	0.081	11.8
VII:	Lolland-Falster	B 0.002	0.101	20.6
VIII:	Bornholm	0.013	0.083	6.3
Mean		0.007	0.082	7.6
Copenhagen		0.079	0.105	15.2
Population-weighted mean		0.027	0.085	9.2
Median		0.003	0.083	6.3
A: counting error: 20-33%; B: counting error > 33%				

5.8.4. Sr-90 and Cs-137 in Various Foods

In December a number of imported foods were provided from shops in Copenhagen. Special importance was attached to the so-called Mikro-Makro foods, which mainly consist of various cereal products, first of all rice. The activity levels in Italian rice were similar to those found in Danish wheat, while the concentrations in rice from Argentina were definitely lower, which is not surprising since accumulated fall-out on the southern hemisphere is only one third of the level on the northern one. As expected, polished rice showed lower levels than unpolished rice.

Table 5.8.4

Sr-90 and Cs-137 in various foods in 1970

Sample	Month	pCi Sr-90/kg	S. U.	pCi Cs-137/kg	M. U.	Country of production
Eggs	Dec.	2.5	4.7	~2	~2	Denmark
Lemon	June	4.3	17	2	3	Italy
Orange	Dec.	7.1	17	8.1	4.2	Spain
Banana	Dec.	0.8	16	0	0	Central America
Grits (Oats)	Dec.	12	2.9	24	12	Denmark
Millet	Dec.	-	-	15	5	-
Soya beans	Dec.	18	9.6	14	1.1	-
Buck wheat	Dec.	8.1	23	0	0	Belgium
Rice polished	Dec.	-	-	15	19	-
Rice polished	Dec.	0.5	5.0	0	0	-
Rice unpolished	Dec.	7.0	55	54	22	Italy
Rice unpolished	Dec.	4.3	34	7.5	7.4	Argentina
Rice unpolished	Dec.	10	62	34	14	Belgium

The variation between locations was in all cases highly significant (cf. Risö Report No. 154, p. 72[1]). The highest Sr-90 levels were found in drinking water from Bornholm, East Jutland and Copenhagen. As compared with previous years, the 1970-Sr-90 levels were mostly lower.

The calcium (and stable strontium) levels were in close agreement with the observations made earlier.

5.9. Estimate of the Mean Contents of Sr-90 and Cs-137 in the Human Diet in Denmark in 1970

5.9.1. The Annual Quantities

The annual quantities are calculated by multiplication of the daily quantities (as stated by E. Hoff-Jørgensen, cf. Risö Report No. 63, table B[1]) by 365.

5.9.2. Milk and Cream

The Sr-90 and Cs-137 contents per kg milk were calculated from the annual mean values for dried milk (cf. tables 5.1.1 and 5.1.3). 1 kg ~1 l milk, containing approx. 1.2 g Ca and 1.66 g K. Hence the mean contents in milk were 8.8 pCi Sr-90/kg and 14 pCi Cs-137/kg.

5.9.3. Cheese

1 kg of cheese contains approx. 8.5 g Ca and 1.2 g K. The Sr-90 and Cs-137 contents in cheese were calculated from these figures and from the S.U. and M.U. levels in dried milk (cf. tables 5.1.1 and 5.1.3). 1 kg of cheese appeared to contain 62 pCi Sr-90 and 10 pCi Cs-137.

5.9.4. Grain Products

Tables 5.9.1 and 5.9.2 show the estimates of Sr-90 and Cs-137 respectively in grain products consumed in 1970. From these tables the activity levels in grain products were estimated at 17.8 pCi Sr-90/kg and 38 pCi Cs-137/kg.

Table 5.9.1

Estimate of the Sr-90 content in grain products consumed per capita in 1970

Type	Fraction from harvest 1969			Fraction from harvest 1970			Total
	kg flour	pCi/kg	pCi	kg flour	pCi/kg	pCi	pCi
Rye flour (100% extraction)	21.9	36.0	788	7.3	31.0	226	1014
Wheat flour (75% extraction)	32.9	6.1	201	10.9	8.0	87	288
Grits	5.5	15.6	86	1.8	22.0	40	126
Total	60.3	17.8	1075	20.0	17.7	353	1428

Table 5.9.2

Estimate of the Cs-137 content in grain products consumed per capita in 1970

Type	Fraction from harvest 1969			Fraction from harvest 1970			Total
	kg flour	pCi/kg	pCi	kg flour	pCi/kg	pCi	pCi
Rye flour (100% extraction)	21.9	59	1292	7.3	85	620	1912
Wheat flour (75% extraction)	32.9	19	625	10.9	29	316	941
Grits	5.5	23	126	1.8	42	76	202
Total	60.3	34	2043	20.0	51	1012	3055

5.9.5. Potatoes

The figures in table 5.5.1 were used, i.e. 3.3 pCi Sr-90/kg and 12.4 pCi Cs-137/kg.

5.9.6. Vegetables

Table 5.6.5 shows the calculation of Sr-90 and Cs-137 in Danish vegetables consumed in 1970. The mean contents were 10 pCi Sr-90/kg and 4.6 pCi Cs-137/kg.

5.9.7. Fruit

The levels in imported fruit in 1970 are assumed to be equal to the mean levels found in lemons, oranges and bananas collected in Copenhagen in 1970, i.e. 4.0 pCi Sr-90/kg and 3 pCi Cs-137/kg (cf. 5.8.4). The mean levels in Danish fruit in 1970 were 2.7 pCi Sr-90/kg and 12 pCi Cs-137/kg (cf. 5.8). The daily mean consumption of fruit consisted of 100 g of Danish and 40 g of foreign origin. Hence the mean contents in fruit were 3.1 pCi Sr-90/kg and 9.4 pCi Cs-137/kg.

5.9.8. Meat

From table 5.8.1 the annual mean values of Sr-90 and Cs-137 in meat were calculated: 1.1 pCi Sr-90/kg and 59 pCi Cs-137/kg. (Danish meat consists of 2/3 pork and 1/3 beef).

5.9.9. Fish

The Sr-90 and Cs-137 contents in fish are shown in table 5.8.2. The means of these figures are used as country mean values for the year, i.e. 0.3 pCi Sr-90/kg and 37 pCi Cs-137/kg.

5.9.10. Eggs

The activity contents in eggs were estimated from the measurements in table 5.8.4. The levels were 2.5 pCi Sr-90/kg and 2 pCi Cs-137/kg.

5.9.11. Coffee and Tea

The levels, measured in 1969, were used, i.e. 27 pCi Sr-90/kg and 168 pCi Cs-137/kg.

5.9.12. Drinking Water

The Sr-90 level found in drinking water collected in June (cf. table 5.8.3) was used as the country mean for drinking water, i.e. 0.03 pCi Sr-90/l. The Cs-137 content in drinking water is assumed to be negligible.

5.9.13. Discussion

Tables 5.9.3 and 5.9.4 show the estimates of Sr-90 and Cs-137 in the Danish diet in 1970. The figures should be compared with the levels calculated from the total-diet samples (cf. 5.7). The Sr-90 estimates obtained by the two methods were 7.3 S.U. and 8.1 S.U. respectively, and the Cs-137 estimates were 32 pCi Cs-137/day and 30 pCi Cs-137/day. Figs. 5.9.1 and 5.9.2 show a comparison between the measured and calculated levels in total Danish diet since 1961. The agreement between the two methods was satisfactory.

The relative contribution of Sr-90 from milk products increased from approx. 38% in 1969 to 44% in 1970, whereas that from grain products decreased from 36 to 31%. The contribution from potatoes, other vegetables and fruit was 19%, i.e. nearly the same as in 1969. The relative contribution of Cs-137 in the total diet changed as follows from 1969 to 1970: Milk products were almost unchanged (19 and 20%), grain products decreased from 28 to 26%, and meat from 30 to 27%.

Table 5. 9. 3

Estimate of the mean content of Sr-90 in the human diet in Denmark in 1970

Type of food	Annual quantity in kg	pCi Sr-90 per kg	Total pCi Sr-90	Percentage of total pCi Sr-90 in food
Milk and cream	164.0	8.8	1443	31.9
Cheese	9.1	62	564	12.4
Grain products	80.3	17.8	1428	31.5
Potatoes	73.0	3.3	241	5.3
Vegetables	43.8	10	438	9.7
Fruit	51.1	3.1	158	3.5
Meat	54.7	1.1	60	1.3
Eggs	10.9	2.5	27	0.6
Fish	10.9	0.3	3	0.1
Coffee and tea	5.5	27	149	3.3
Drinking water	548.0	0.03	16	0.4
Total			4527	

The mean calcium intake was estimated at 620 g (approx. 200-250 g Creta praeparata). Hence the Sr-90/Ca ratio in the total diet was 7.3 S. U. in 1970.

Table 5. 9. 4

Estimate of the mean content of Cs-137 in the human diet in Denmark in 1970

Type of food	Annual quantity in kg	pCi Cs-137 per kg	Total pCi Cs-137	Percentage of total pCi Cs-137 in food
Milk and cream	164.0	14	2296	19.8
Cheese	9.1	10	91	0.8
Grain products	80.3	38	3051	26.3
Potatoes	73.0	12.4	905	7.8
Vegetables	43.8	4.6	201	1.7
Fruit	51.1	9.4	480	4.1
Meat	54.7	59	3227	27.8
Eggs	10.9	2	22	0.2
Fish	10.9	37	403	3.5
Coffee and tea	5.5	168	924	8.0
Drinking water	548	0	0	0
Total			11600	

As the approximate intake of potassium was 1365 g, the pCi Cs-137/g K ratio was approx. 8.5. The daily mean intake in 1970 was 32 pCi Cs-137 per capita.

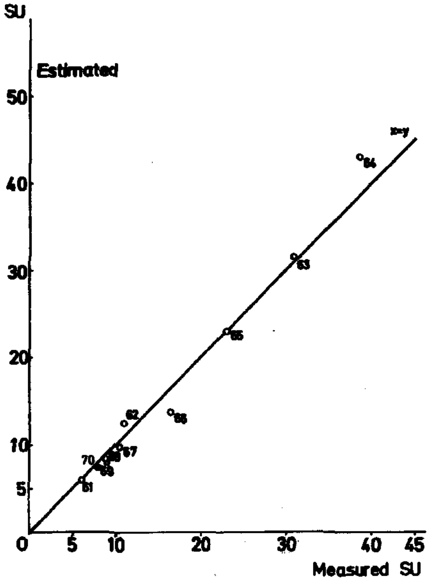

Fig. 5.9.1. A comparison between estimated (cf. 5.9) and measured (cf. 5.7) Sr-90 levels in total Danish diet 1961-70

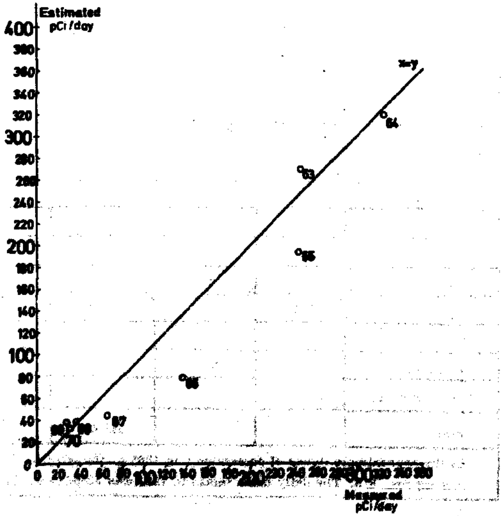

Fig. 5.9.2. A comparison between estimated (cf. 5.9) and measured (cf. 5.7) Cs-137 levels in total Danish diet 1962-70

6. STRONTIUM-90 AND CAESIUM-137 IN MAN IN 1970

6.1. Sr-90 in Human Bone

The collection of human vertebrae from the institutes of forensic medicine in Copenhagen and Århus was continued in 1970. As in the total-food survey (cf. 5.7), the country was divided into eight zones. The samples were divided into five age groups: new-born (⟨1 month), infants (1 month - 4 years), children and teen-agers (5 - 19 years), adults (≤29 years) and adults (⟩29 years).

Tables 6.1.1 - 6.1.5 show the results for the five groups.

The levels were lower in 1970 than in 1969 for all age groups except infants. The highest levels in vertebrae were found in the infant and children groups, the lowest among new-born (cf. fig. 6.1). Adults between 20 and 29 years showed as previously higher levels than adults of more than 29 years. The levels were lower than expected (cf. Appendix C).

As in the previous years[1)], the mean OR: S.U. (new born's bone)/S.U. (mother's diet during pregnancy) was calculated from tables 6.1.1, 5.7.1 and 5.7.2 and Risö Report No. 220, tables 5.7.1 and 5.7.2[1)]. Tables 6.1.7 shows the result compared with the OR values from previous years.

Table 6.1.1

Sr-90 in bone from new-born children (⟨1 month old) in 1970

Zone	Age in days	Month of death	Sex	pCi Sr-90/g Ca	Sample no.
I	11	3	M	1.63	MK 3
I	23	5	F	0.91	MK 62
I	8	5	F	0.90	MK 72
II	9	6	M	0.71	MK 98
II	26	5	F	0.42	MK 94
II	1	2	M	1.04	MK 12
II	6	2	M	0.89	MK 19
II	2	3	F	1.20	MK 29
II	27	4	F	1.02	MK 41
II	4	3	F	0.48	MK 45
II	8	5	M	1.01	MK 63
II	1	5	F	0.56	MK 71
II	5	6	M	0.96	MK 86
III	10	2	-	1.46	MK 20
III	2	3	-	1.04	MK 48
III	6	6	M	0.78	MK 89
III	6	6	F	0.99	MK 92
IV	1	2	M	0.66	MK 16

Table 6.1.2

Sr-90 in bone from infants (<4 years old) in 1970

Zone	Age in years and months	Month of death	Sex	pCi Sr-90/g Ca	Sample no.
I	6 m	2	F	1.80	MK 24
I	4 m	2	F	1.14	MK 30
I	4 m	5	M	2.64	MK 73
I	2 y	6	F	2.53	MK 96
II	8 m	2	F	2.01	MK 10
II	3 y 6 m	1	M	2.00	MK 14
II	3 m	2	M	1.03	MK 21
II	3 y 5 m	2	F	1.23	MK 23
II	7 m	3	M	4.18	MK 26
II	1 m	2	F	0.88	MK 28
II	1 m	3	M	0.81	MK 42
II	3 y 6 m	3	M	1.70	MK 44
II	4 m	4	M	1.28	MK 47
II	1 y 5 m	4		1.72	MK 50
II	5 m	5	M	1.94	MK 64
II	1 y	6	F	2.34	MK 83
II	11 m	6	F	2.00	MK 84
II	2 y	6	F	1.76	MK 88
II	1 1/2 m	6	M	1.65	MK 99
II	3 m	6	F	2.00	MK 101
III	2 m	1	M	0.97	MK 13
III	3 y 9 m	4	F	1.44	MK 49
III	2 y 6 m	3	F	1.50	MK 61
III	1 m	6	F	0.94	MK 93
IV	2 m	2	F	1.78	MK 11
IV	7 m	6	M	1.97	MK 97
IV	1 1/2 m	6	F	0.70	MK 100
VI	2 m	5	F	2.09	MK 56
VI	3 y 10 m	5	F	2.29	MK 57
VI	4 m	5	F	1.78	MK 75
VI	4 y	5	-	0.81	MK 79
VI	1 y 10 m	7	F	1.29	MK 106
VI	4 m	8	M	6.15	MK 114
VI	9 m	9	M	2.16	MK 115
VI	4 m	9	M	1.12	MK 117
VI	1 y	9	F	2.23	MK 148
VI	7 m	9	M	1.92	MK 150
VI	2 y	9	-	1.64	MK 151
VI	4 m	11	F	1.71	MK 152
VI	5 m	11	M	2.50	MK 153
VI	4 m	11	F	2.07	MK 131
VI	5 m	11	M	2.69	MK 134

Table 8.1.3

Sr-90 in bone from children and teen-agers (<19 years) in 1970

Zone	Age in years	Month of death	Sex	pCi Sr-90/g Ca	Sample no.
I	19	2	M	2.44	MK 17
I	11	5	M	1.95	MK 85
I	7	6	M	2.11	MK 87
I	9	6	M	1.02	MK 102
II	5 1/2	2	F	1.78	MK 15
II	9	2	F	1.75	MK 22
II	19	3	M	1.36	MK 25
II	13	3	M	0.89	MK 27
II	14	3	M	1.28	MK 40
II	14	5	M	3.85	MK 43
II	5	4	M	1.46	MK 46
II	16	5	M	1.75	MK 60
II	9	6	M	1.17	MK 90
II	19	6	M	1.02	MK 91
II	7	5	F	1.39	MK 95
III	17	2		2.07	MK 18
III	14	5	M	1.16	MK 65
III	15	5	F	1.34	MK 66
VI	13	2	F	1.09	MK 7
VI	15	3	M	1.37	MK 34
VI	7	4	F	3.77	MK 54
VI	19	5	M	1.23	MK 80
VI	7	5	F	1.53	MK 82
VI	13	8	F	0.84	MK 105
VI	16	6	M	0.47	MK 107
VI	11	7	M	1.11	MK 109
VI	18	9	M	1.35	MK 111
VI	10	9	M	1.47	MK 119
VI	15	9	M	1.44	MK 143
VI	16	10	F	0.78	MK 147
VII	18	2	M	1.04	MK 4

Table 6.1.4

Sr-90 in vertebrae from adults (≥20 years) in 1970

Zone	Age in years	Month of death	Sex	pCi Sr-90/g Ca	Sample no.
II	29	11	M	1.08	MK 142
VI	23	2	M	1.72	MK 1
VI	20	2	M	1.25	MK 32
VI	28	4	M	1.40	MK 58
VI	23	4	F	1.33	MK 59
VI	24	5	F	0.90	MK 76
VI	27	5	M	1.49	MK 77
VI	24	8	M	0.80	MK 104
VI	20	8	F	1.07	MK 110
VI	20	6	M	0.99	MK 81
VI	29	3	M	1.32	MK 38
VI	27	8	M	2.04	MK 112
VI	23	9	M	1.84	MK 113
VI	25	9	M	0.58	MK 118
VI	20	11	F	2.99	MK 129
VI	21	11	F	1.40	MK 130
VI	21	10	M	2.19	MK 145

Table 6.1.3

Sr-90 in vertebrae from adults (> 20 years old) in 1970

Zone	Age in years	Month of death	Sex	pCi Sr-90/g Ca	Sample No.
II	43	11	F	1.07	MK 121
II	40	11	F	1.03	MK 122
II	44	11	F	1.01	MK 123
II	46	11		0.94	MK 124
II	34	11	M	1.46	MK 125
II	69	12	F	1.67	MK 136
II	45	12	M	1.28	MK 137
II	47	12	M	0.86	MK 138
II	56	12	M	1.41	MK 139
II	70	12	M	1.88	MK 140
II	93	12	M	1.10	MK 141
VI	49	2	M	1.47	MK 8
VI	30	3	F	1.64	MK 35
VI	31	2	M	1.40	MK 36
VI	44	11(69)	M	2.03	MK 37
VI	47	5	M	1.15	MK 53
VI	32	6	F	1.64	MK 55
VI	39	5	M	0.97	MK 74
VI	39	5	M	0.86	MK 78
VI	39	8	M	0.69	MK 108
VI	33	3	M	1.11	MK 33
VI	53	3	F	0.76	MK 39
VI	39	3	M	1.00	MK 31
VI	33	9	F	1.06	MK 116
VI	37	8	F	0.92	MK 120
VI	30	11	F	1.05	MK 127
VI	34	10	F	0.77	MK 128
VI	30	11	F	1.46	MK 132
VI	52	11	F	1.28	MK 133
VI	41	11	M	0.60	MK 135
VI	41	10	M	1.04	MK 144
VI	52	9	F	0.95	MK 146

Table 6.1.6

Sr-90 (pCi/g Ca) in human vertebrae collected in Denmark in 1970

Age group	Number of samples	Min.	Max.	Median	Mean
New-born (< 1 month)	18	0.42	1.63	0.91	0.93
Infants (≤ 4 years)	42	0.70	6.15	1.78	1.87
Children (≤ 19 years)	31	0.47	3.85	1.36	1.52
Adults (≤ 29 years)	17	0.58	2.99	1.33	1.44
Adults (≥ 30 years)	32	0.60	2.03	1.06	1.18

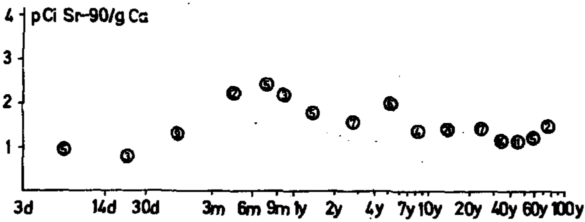

Fig. 6.1. Sr-90 in human vertebrae in 1970 (the figures in the circles indicate the number of samples).

Table 6.1.7

Observed ratios:

OR S.U. new borns' bone/S.U. mothers' diet during pregnancy 1963-70

Year	1963	1964	1965	1966	1967	1968	1969	1970	Mean
OR	0.11	0.09	0.08	0.09	0.13	0.13	0.11	0.10	0.105
SD	0.04	0.02	0.03	0.03	0.06	0.05	0.05	0.03	0.019
SE	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.007

Table 6.2

Whole-body measurements of caesium-137 and potassium in 1970

No.	Sex	Counting date	Age	Height in cm	Weight in kg	Daily milk consumption	M. U. in body	Body burden in nCi Cs-137	g K/kg body weight
88 a	f	9/4	33	164	61	1/4	32.0	2.11	1.15
94 b	f	14/4	49	176	62	1/4	23.4	2.87	1.98
93 c	m	14/4	45	174	87	0	26.4	4.52	1.97
98 d	f	10/4	42	171	65	1/2	38.6	3.96	1.58
74 e	m	17/4	32	174	72	1/4	46.5	6.15	1.84
76 f	f	17/4	31	180	71	1/2	91.6	1.09	1.82
82 g	f	15/4	23	164	46	1/4	66.0	4.18	1.38
86 i	m	14/4	41	170	66.5	0	36.6	3.76	1.55
84 j	f	14/4	27	158	45	1/4	40.6	3.00	1.10
80 k	f	16/4	38	161	55	1/4	7.18	0.81	2.05
89 l	m	9/4	38	172	66	3/4	25.2	2.68	1.61
75 m	m	17/4	38	193	80	1/4	38.1	5.35	1.75
92 p	f	10/4	38	178	63.5	0	20.3	1.55	1.20
87 q	m	9/4	40	192	86.5	1/2	21.6	3.73	2.0
83 u	f	16/4	31	162	53.0	1/4	25.5	1.70	1.26
96 v	m	13/4	28	174	74.5	1/2	24.0	2.84	1.59
91 y	f	10/4	22	165	52.0	1/4	35.0	2.56	1.39
97 z	m	13/4	31	178	80.0	1/4	19.4	2.66	1.73
78 æ	f	15/4	35	160	53.0	1/4	33.2	2.29	1.30
85 ø	f	14/4	31	160	56.5	1/2	16.2	1.05	1.16
73 å	m	21/4	47	183	76.0	1/4	17.6	2.63	1.97
116 a	f	23/7	33	164	60.0	1/4	12.3	0.77	1.05
113 b	f	15/7	49	176	64.0	1/4	15.4	1.76	1.4
119 c	m	15/7	45	174	87.0	0	35.9	4.88	1.57
101 d	f	8/7	42	171	64.0	1/2	31.7	2.74	1.35
112 e	m	28/7	32	174	75.0	1/4	26.9	4.18	2.07
117 f	f	28/7	31	180	73.0	1/2	9.83	1.21	1.68
114 g	f	20/7	23	164	47.5	1/4	14.0	0.92	1.38
115 i	m	20/7	41	170	64.0	0	12.4	1.78	2.25
110 j	f	14/7	27	158	47	1/4	14.0	0.79	1.19
121 k	f	17/8	38	161	55	1/4	18.3	1.36	1.35
102 l	m	8/7	38	172	64	3/4	20.8	2.04	1.63
99 m	m	7/7	38	193	80	1/4	44.4	6.16	1.73
107 p	f	13/7	38	178	63	1/4	13.4	1.01	1.2
108 q	m	13/7	40	192	87,5	1/2	23.3	3.45	1.69
105 u	f	9/7	31	162	52	1/4	35.0	1.67	1.28
103 v	m	8/7	28	174	74.5	1/2	13.2	1.69	1.72
109 x	f	13/7	46	161	60,0	0	34.4	1.82	1.24
100 y	f	7/7	22	165	58.0	1/4	17.5	1.37	1.35
104 z	m	8/7	31	178	77.0	1/4	12.5	1.59	1.65
106 æ	f	13/7	35	160	54.5	1/4	9.6	0.65	1.35
118 ø	f	28/7	31	160	55.0	1/2	17.0	1.37	1.42
111 å	m	14/7	47	183	74.0	1/4	19.7	2.03	2.01

No.	Sex	Counting date	Age	Height in cm	Weight in kg	Daily milk consumption	M. U. in body	Body burden in nCi Cs-137	g K/kg body weight
168 b	f	9/12	49	176	64.0	1/4	17.8	1.81	1.59
189 c	m	14/12	45	174	87.0	0	27.6	4.33	1.80
161 d	f	9/12	42	171	64.0	1/2	35.7	4.11	1.80
191 e	m	14/12	32	174	72.0	1/4	20.1	2.53	1.76
163 g	f	9/12	23	164	44.5	1/4	12.9	1.21	2.11
115 i	m	20/7	41	170	64.0	0	12.4	1.78	2.25
157 k	f	8/12	38	161	55.0	1/4	20.8	2.07	1.81
113 l	m	7/12	38	172	64.0	3/4	34.0	3.34	2.20
171 m	m	10/12	38	193	79.5	1/4	26.5	3.71	1.76
195 p	f	14/12	39	178	66.0	1/4	11.6	1.19	1.57
174 q	m	9/12	40	192	89.0	1/2	20.2	3.37	1.87
158 v	m	8/12	28	174	75.0	1/2	23.1	3.18	1.84
117 x	f	7/12	46	161	60.0	0	17.0	1.66	1.63
172 z	m	10/12	31	178	78.0	1/4	13.7	2.04	1.90
114 å	m	7/12	47	183	75.0	1/4	13.7	2.25	2.18

6.2. Cs-137 in the Human Body

In July 1963, whole-body measurements were initiated at Risö in the low-level counting room in the Health Physics Department (cf. 2.3. in Risö Report No. 85[1]). A control group from the Health Physics Department was selected and has since then been measured three times a year.

Table 6.2 shows the results. The control group is indicated by small letters in the table.

The annual mean value of the control group was 23 pCi Cs-137/g K. As earlier, we shall consider this figure representative of the mean of the Danish population in 1970. The total-body content of Cs-137 in 1970 for a standard man containing 140 g of potassium equals $140 \cdot 23 \cdot 10^{-3}$ nCi = 3.2 nCi Cs-137, i.e. approx. 60% of the 1969 level.

The decrease from 1969 to 1970 is surprising. At the moment we believe that the 1969 and perhaps also the 1968 levels were overestimated. The whole-body countings in 1970 were performed with the new 8" x 4" NaI crystal, which improved the counting efficiency. Furthermore, the γ-spectra were calculated on computer in 1970. These modifications might both account for the abrupt change in the Cs-137 values from 1969 to 1970.

Fig. 6.2. shows the mean M.U. values (with one S.D.) for men and women measured in 1963-1970.

The maximum was reached in August 1964. The figure also shows that the mean level in the male group was approx. 1.3 - 1.5 times as high as that in the female group (cf. also Appendix C).

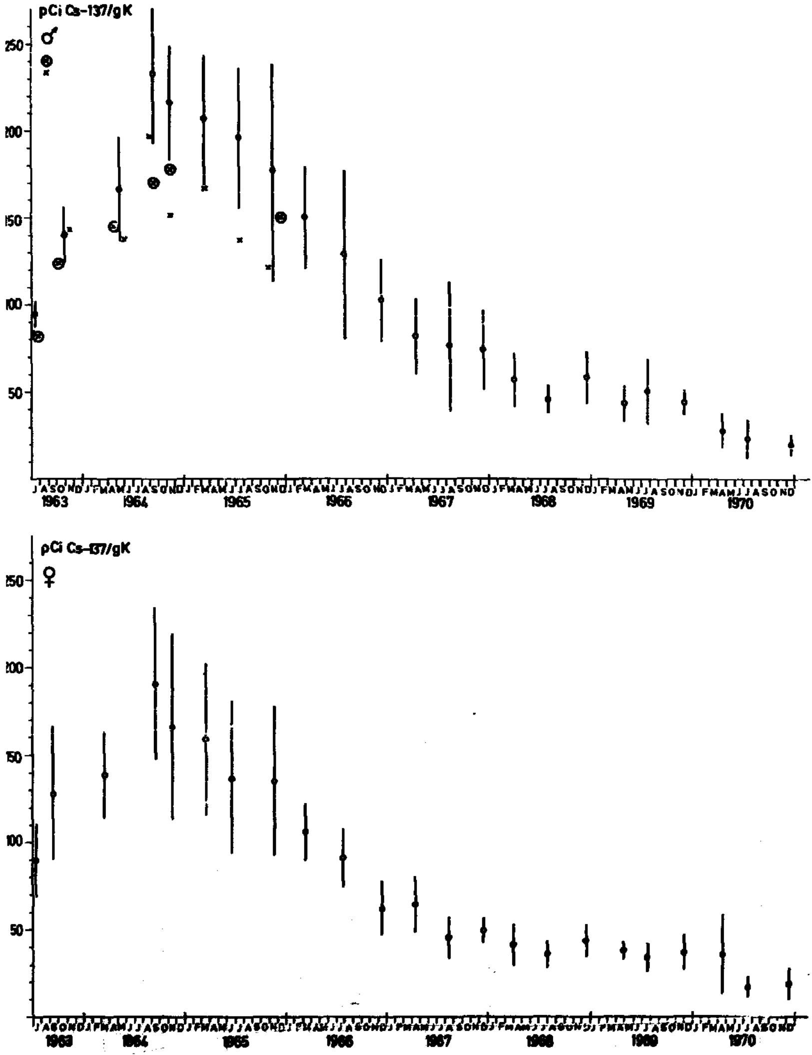

Fig. 6.2. Cs-137 mean levels in humans, 1963-70 (1 S.D. indicated)

Table 7.1

Sr-90 in sea water collected around Zealand in June and Dec. 1970

Location	Position		June			December		
	N	E	depth in m	pCi/l	Salinity o/oo	depth in m	pCi/l	Salinity o/oo
Kullen	56°15'	12°25'	0	0.70	20.0	0	0.80	16.6
"						20	0.65	32.0
Hesselø	56°10'	11°47'	0	0.53	19.4	0	0.53	21.2
"							lost	
Kattegat SW	56°07'	11°10'	0	0.74	18.4	0	0.50	21.6
"							lost	
Asnæs rev	55°38'	10°47'	0	0.70	17.7	0	0.60	20.3
"						38	0.48	28.1
Halskov rev	55°20'	11°02'	0	0.70	17.6	0	0.67	18.5
"						45	0.54	28.1
Langeland bælt	54°52'	10°50'	0	0.64	20.1	0	0.41	25.0
"						35	0.07	20.9
Femern bælt	54°36'	11°05'	-	-	-	0	0.48	18.1
"						27	0.68	19.5
Gedser rev	54°28'	12°13'	0	0.73	12.8	0	0.74	13.7
"						25	0.60	16.7
Stevns	55°16'	12°34'	0	0.93	8.8	0	0.83	9.5
"						22	0.86	19.1
The Sound - South	55°25'	12°39'	-	-	-	0	0.74	9.9
"							lost	
The Sound - North A	55°48'	12°44'	0	0.54	18.9	0	0.61	18.3
"						19	0.42	26.9
The Sound - North B	55°59'	12°42'	0	0.34	19.7	0	0.60	17.7
"						20	0.49	28.8
Mean			surface	0.66	17.3	surface	0.63	17.5
SD				0.16	3.7		0.13	4.6
SE				0.05	1.2		0.04	1.8
Mean			bottom	-	-	bottom	0.53	24.2
SD				-	-		0.22	5.2
SE				-	-		0.07	1.7

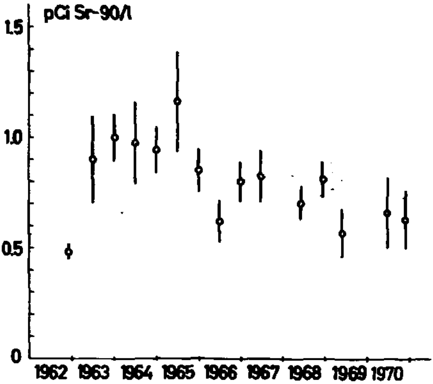

Fig. 7.1. Sr-90 in sea water from inner Danish waters, 1962-70 (1 S.D. indicated)

7. STRONTIUM-90 IN SEA WATER IN 1970

The collection of sea-water samples initiated in 1961-62 was continued in 1970. The samples were collected by our new ship "Fyrholm" in June and December around Zealand at new locations, which, however, were rather similar to those used previously[1].

Fig. 7.1 shows the mean content of Sr-90 in sea water collected since November-December 1962 in inner Danish waters (cf. also fig. 5.8.2). The levels have been rather constant in recent years.

8. SPECIAL SURVEYS

8.1. Meteorological Mast Experiment

As in the previous years, samples of precipitation were collected from the meteorological mast at Risö at eight different heights (cf. fig. 3.1.2.2).

Table 8.1.1 shows the Sr-90 levels in the eight bottles throughout the year and tables 8.1.2 and 8.1.3 the analysis of variance of the natural logarithm of the pCi Sr-90/l and the mCi Sr-90/km^2 figures respectively. As previously, the variations between months were highly significant (P > 99.95%), and so were variations of different locations.

Table 8.1.1

Sr-90 in the meteorological mast 1970

	0 m		7 m		23 m		39 m	
	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2
Jan.	1.38	0.009	1.62	0.008	2.49	0.024	3.13	0.026
Feb.	1.45	0.009	1.68	0.006	1.94	0.006	3.59	0.013
Mar.	0.85	0.037	1.10	0.043	1.08	0.040	1.31	0.043
Apr.	1.14	0.068	1.30	0.069	1.50	0.069	1.59	0.086
May	5.00	0.106	6.67	0.145	6.56	0.134	6.37	0.135
June	4.53	0.126	4.93	0.131	5.53	0.139	6.31	0.176
July	2.65	0.139	2.96	0.142	3.22	0.176	3.78	0.175
Aug.	1.85	0.089	2.23	0.121	2.09	0.108	1.90	0.091
Sep.	1.45	0.075	1.28	0.061	1.40	0.075	1.50	0.070
Oct.	0.64	0.045	0.57	0.041	0.84	0.060	0.63	0.045
Nov.	0.55	0.039	0.64	0.045	0.64	0.045	0.65	0.046
Dec.	0.61	0.022	(0.64)	(0.023)	0.80	0.033	0.90	0.045
1970	$\bar{x}$ 1.54	Σ 0.764	$\bar{x}$ 1.74	Σ 0.835	$\bar{x}$ 1.87	Σ 0.909	$\bar{x}$ 1.97	Σ 0.951
	495 mm		480 mm		485 mm		481 mm	

	56 m		72 m		96 m		123 m		Mean	
	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2
Jan.	2.15	0.017	2.72	0.021	3.38	0.017	2.06	0.005	2.37	0.016
Feb.	3.79	0.011	3.75	0.011	8.24	0.028	9.28	0.009	4.22	0.012
Mar.	1.16	0.032	1.39	0.038	1.46	0.034	1.48	0.024	1.23	0.036
Apr.	1.65	0.080	1.53	0.074	1.94	0.090	2.56	0.065	1.65	0.075
May	6.79	0.126	7.34	0.169	6.45	0.115	6.56	0.095	6.47	0.128
June	5.15	0.122	6.44	0.166	5.24	0.117	5.05	0.125	5.40	0.138
July	2.73	0.131	2.94	0.133	3.71	0.180	3.32	0.117	3.16	0.149
Aug.	2.05	0.086	2.20	0.101	2.18	0.073	2.00	0.076	2.06	0.093
Sep.	1.25	0.055	1.39	0.065	1.46	0.065	1.43	0.049	1.39	0.064
Oct.	0.54	0.038	0.66	0.046	0.70	0.049	1.04	0.060	0.70	0.048
Nov.	0.56	0.040	0.65	0.046	0.73	0.052	0.73	0.038	0.64	0.044
Dec.	0.70	0.024	0.56	0.022	0.54	0.017	0.90	0.021	0.71	0.026
1970	$\bar{x}$ 1.72	Σ 0.762	$\bar{x}$ 1.96	Σ 0.892	$\bar{x}$ 2.01	Σ 0.837	$\bar{x}$ 2.11	Σ 0.684	$\bar{x}$ 1.74	Σ 0.829
	442 mm		455 mm		487 mm		524 mm		447 mm	

Table 8.1.2

Analysis of variance of ln pCi Sr-90/l in precipitation in 1970
(from table 8.1.1)

Variation	SSD	f	s^2	v^2	P
Between locations	1.6954	7	0.2422	4.05	>99.9 %
Between months	52.2653	11	4.7514	79.45	>99.95 %
Remainder	4.5481	76	0.0598		
η = 0.25					

Table 8.1.3

Analysis of variance of ln mCi Sr-90/km^2 in precipitation in 1970
(from table 8.1.1)

Variation	SSD	f	s^2	v^2	P
Between locations	2.6317	7	0.3760	2.47	>97.5 %
Between months	57.3120	11	5.2102	34.21	>99.95 %
Remainder	11.5717	76	0.1523		
η = 0.40					

The mean amount of precipitation in the eight bottles on the mast was 447 mm in 1970, i.e. 90% of the level measured in rain bottles at ground level at Risö (cf. table 3.2.4.1). The total deposition was 0.83 mCi Sr-90/km^2, i.e. nearly equal to the level measured at the ground stations at Risö (cf. 3.2.4).

8.2. Levels of Sr-90 and Cs-137 in Grass and Milk from the Entire Country

In September grass and milk samples were as previously collected from the State experimental farms (cf. fig. 4.1.1). (As no milk was obtainable from Virumgård, this farm was omitted from the sampling.)

Table 8.2.1 shows the Sr-90 and Cs-137 contents in grass and milk from the sample collection. The mean Sr-90 level in grass was in September 74 S.U. (in 1969 the September level was 63 S.U.), and the mean level at Risö (cf. table 3.2.2) in July-September 1970 was 67 S.U.

The mean milk levels were 5.8 S.U. and 10 M.U. In dried milk we found in September 7.2 S.U. and 13.2 M.U.

The OR between mean S.U. in milk and grass was 0.08 in 1970 i.e. nearly the same as in 1965-69.

Table 8.2.1

Sr-90 and Cs-137 in grass and milk in Sept. 1970 collected on the State experimental farms

	Milk pCi Sr-90/g Ca	Milk pCi Cs-137/g K	Milk pCi Cs-137/l	Grass pCi Sr-90/g Ca	Grass pCi Cs-137/g K	Grass pCi Cs-137/kg	S.U. milk / S.U. grass	Milk M.U./S.
Tylstrup	4.0	19	32	83	15	111	0.05	4.8
Studsgård	8.8	10	16	121	10	72	0.07	1.1
Ødum	5.0	6	10	46	33	90	0.11	1.2
Askov	6.8	17	28	128	26	69	0.05	2.5
St. Jyndevad	10.0	9	14	96	13	67	0.10	0.9
Blangstedgård	3.3	4	7	46	19	62	0.07	1.2
Vemmetofte	3.9	8	12	36	5	37	0.11	2.1
Abed	6.2	7	11	51	35	132	0.12	1.1
Åkirkeby	4.0	7	11	62	15	69	0.06	1.8
Mean	5.8	10	16	74	19	79	0.08	1.9
S.D.	2.4	5	9	34	10	28	0.03	1.2
η	0.40	0.52	0.55	0.46	0.54	0.36	0.34	0.66

8.3. Human Milk

No human milk samples were collected in 1970.

8.4. Country-wide Measurement of the γ-Background in 1970

8.4.1. State Experimental Farms

As in the previous years[1], the γ-background was measured in March, June, September, and December at ten State experimental farms. Table 8.4.1.1 shows the results, and table 8.4.1.2 gives the analysis of variance. The variations between locations and between months were highly significant (P > 99.95%). As in the previous years, it was evidently not the fall-out that determined the variation between locations. The 1970 levels were lower than the 1969 levels.

Fig. 8.4 shows the γ-background in four groups of sampling stations since 1962. The fact that stations with a low fall-out rate and a high clay content in the soil (Abed, Blangstedgård and Tystofte) show higher γ-levels than stations with a high fall-out rate and a low clay content (but a high sand content) (Studsgård, St. Jyndevad and Askov) was discussed in Risö Report No. 154[1].

Table 8.4.1.1

Y-background at the State experimental farms in 1970 (μR/h)

	Mar.*	June	Sep.	Dec.	Mean
Tylstrup	5.0	5.1	4.7	5.0	4.9
Studsgård	2.9	4.5	4.1	4.4	4.0
Ødum	5.8	6.3	5.8	6.0	6.0
Askov	3.2	6.0	4.7	5.0	4.7
St. Jyndevad	3.2	4.2	3.5	4.0	3.7
Blangstedgård	4.4	6.9	5.8	5.7	5.7
Tystofte	6.7	6.9	6.1	6.4	6.5
Virumgård	5.3	7.5	6.1	6.7	6.4
Abed	2.9	4.8	4.9	5.0	4.4
Åkirkeby	(6.8)	8.4	6.1	9.0	7.6
Mean	4.6	6.1	5.2	5.7	5.4

*Approx. 20 cm show cover at most locations.

Table 8.4.1.2

Analysis of variance of the Y-background at the State experimental farms in 1970 (from table 8.4.1.1)

Variation	SSD	f	s^2	v^2	P
Between locations	50.6382	9	5.6265	15.76	>99.95 %
Between months	11.0794	3	3.6931	10.34	>99.95 %
Remainder	9.2828	26	0.3570		
η = 0.11					

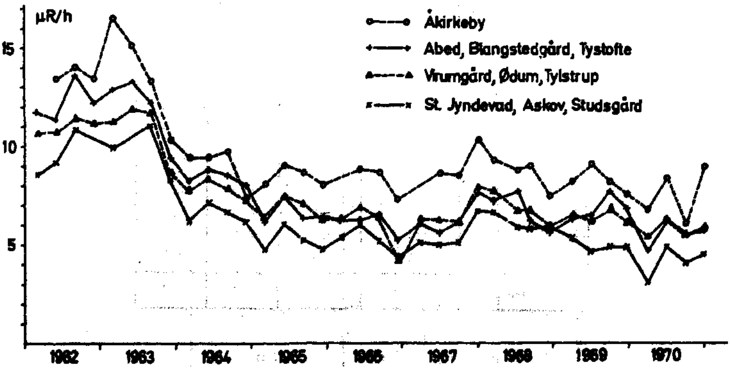

Fig. 8.4. The γ-background at the State experimental farms, 1962-70

Table 6.4.2.1

γ-background (μR/h) in the five zones around Risö in 1970

Risö zone (cf. coloured map)	Location	April	July	Mean
I	1	7.7	7.8	7.8
-	2	7.4	7.5	7.5
-	3	19.7	18.6	19.2
-	4	6.6	11.4	10.0
-	5	8.6	6.6	6.6
Mean		10.0	10.4	10.2
II	1	4.9	5.7	5.3
-	2	7.1	7.5	7.3
-	3	6.0	6.0	6.0
-	4	6.3	6.3	6.3
Mean		6.1	6.4	6.3
III	1	6.0	5.7	5.9
-	2	5.7	7.5	6.6
-	3	6.3	6.0	6.2
-	4	6.6	6.3	6.5
Mean		6.1	6.4	6.3
IV	1	5.7	6.0	5.9
-	2	5.4	6.6	5.7
-	3	5.7	6.0	5.9
-	4	5.4	6.6	6.0
-	5	5.1	6.0	5.6
-	6	5.7	5.7	5.7
-	7	6.6	6.6	6.6
-	8	6.3	6.3	6.3
Mean		5.7	6.2	6.0
V	1	5.7	6.0	5.9
-	2	5.4	6.0	5.7
-	3	6.0	6.0	6.0
-	4	6.3	6.6	6.5
-	5	6.8	7.2	7.0
-	6	5.7	6.9	6.3
-	7	6.3	6.9	6.6
-	8	6.3	7.2	6.8
-	9	6.0	6.0	6.0
-	10	5.7	6.0	6.9
-	11	6.0	6.6	6.3
-	12	5.4	6.0	5.7
Mean		6.0	6.5	6.3

Table 8.4.3.1

γ-background (μR/h) around a location in Zeeland in 1970

Zone and sector	April	July	Mean
A 2	5.8	5.4	5.6
A 3	5.5	5.4	5.5
A 4	7.0	7.2	7.1
A 5	5.8	6.0	5.9
A 6	5.8	6.3	6.1
A 7	5.8	6.0	5.9
A 8	5.8	5.7	5.8
A 9	5.8	6.0	5.9
Mean	5.9	6.0	6.0
B 1	5.8	6.0	5.9
B 2	6.2	6.6	6.4
B 3	5.5	6.3	5.9
B 4	5.8	6.0	5.9
B 5	5.8	6.3	6.1
B 6	6.2	6.3	6.3
B 7	5.5	6.0	5.8
B 8	7.0	6.9	7.0
B 9	5.8	6.3	6.1
B 10	6.2	6.3	6.3
Mean	6.0	6.3	6.2
C 1	5.5	5.4	5.5
C 2	5.3	5.4	5.4
C 3	8.2	6.6	7.4
C 4	5.5	6.3	5.9
C 5	5.5	6.0	5.8
C 6	5.8	6.0	5.9
C 7	6.7	6.6	6.7
C 8	6.4	6.3	6.4
C 9	2.3	6.3	4.3
C 10	7.3	6.9	7.1
C 11	6.4	6.3	6.4
C 12	5.5	6.0	5.8
Mean	5.9	6.2	5.1
D 1	5.3	6.6	6.0
D 2	6.2	6.0	6.1
D 3	5.3	5.7	5.5
D 4	5.8	6.0	5.9
D 5	7.0	6.0	6.5
D 6	6.2	7.8	7.0
D 7	5.8	6.0	5.9
D 8	6.7	6.0	6.4
D 9	5.3	5.7	5.5
D 10	7.3	6.6	7.0
D 11	5.8	6.0	5.9
D 12	4.4	5.4	4.9
Mean	5.9	6.2	6.1

8.4.2. The Risö Environment

γ-background measurements were performed in the five zones round Risö in April and July. The measurements were carried out at the locations where grass and soil are collected (cf. figs. 3.1.2.1 and 3.1.2.2 (the coloured map)).

Table 8.4.2.1 shows the results.

In all locations in zone I and in location 2 in zone II the γ-background was increased because of the various radiation sources at the research establishment. The weighted annual mean for zones III-V was 6.2 μR/h, i.e. a little lower than found in 1969. In zone I the surplus activity from the research establishment was 10.2 - 6.2 = 4 μR/h (in 1967: 4.0, in 1968: 3.9, and in 1969: 3.3). A man working in the open in the Risö area 40 hours a week for 45 weeks a year would thus get a surplus dose of 7 mR/year, i.e. less than 7% of his dose from the natural background, from the research establishment.

8.4.3. A Location in Zealand

As it is important to have knowledge of the preoperational radiation-levels of a nuclear power plant, it was in 1967 decided to initiate such measurements at a location in Zealand(and one in Jutland) which might be used for nuclear power plants in the future.

The area around the location was divided into four zones: A, B, C, and D, with radii of 5, 10, 15, and 20 km respectively. The zones were each divided into 12 30° sectors, sector 1 being from straight north and 30° clockwise, sector 2 from 30 to 60° and so on. A measuring location was thus determined by a zone letter and a sector number. Locations in the sea were omitted.

Table 8.4.3 shows the results. The annual mean for all locations was 6.1 μR/h, i.e. equal to the level found in zone III-V around Risö, but lower than in previous years.

8.4.4. A Location in Jutland

Table 8.4.4 shows a similar investigation as in 8.4.3 for a location in Jutland. The annual mean for all locations was 6.1 μR/h, i.e. equal to the levels of Zealand (cf. 8.4.2 and 8.4.3), but lower than in 1967-69.

8.4.5. The Coasts of the Great Belt

The Great Belt is a main shipping route for international traffic through the inner Danish waters. Occasionally this waterway will be passed by

Table 8.4.4.1

γ-background (μR/h) around a location in Jutland in 1970

Zone and sector	April	July	Mean
A 1	6.6	6.0	6.3
A 2	7.1	6.0	6.6
A 3	6.8	6.3	6.6
A 4	4.9	4.8	4.9
A 5	6.8	6.3	6.6
A 6	4.6	5.1	4.9
A 7	5.7	6.0	5.9
A 8	5.4	5.7	5.6
A 9	6.0	5.7	5.9
A 10	5.7	6.0	5.9
A 11	6.8	6.3	6.6
A 12	6.3	6.6	6.5
Mean	6.1	5.9	6.0
B 1	5.7	6.0	5.9
B 2	6.0	6.3	6.2
B 3	5.7	5.4	5.6
B 4	6.6	6.3	6.5
B 5	5.7	6.3	6.0
B 6	6.6	6.3	6.5
B 7	6.8	6.6	6.7
B 8	6.3	5.7	6.5
B 9	6.0	6.0	6.0
B 10	5.7	6.0	5.9
B 11	5.7	6.3	6.0
B 12	6.6	6.6	6.6
Mean	6.3	6.2	6.3
C 1	6.0	6.3	6.2
C 2	6.3	6.3	6.3
C 3	4.9	4.8	4.9
C 4	6.8	7.2	7.0
C 5	6.6	6.6	6.6
C 6	5.4	5.7	5.6
C 7	6.6	6.6	6.6
C 8	5.7	6.0	5.9
C 9	6.8	6.9	6.9
C 10	5.7	5.7	5.7
C 11	5.4	5.4	5.4
C 12	6.3	6.3	6.3
Mean	6.0	6.2	6.1
D 1	6.0	6.0	6.0
D 2	6.6	6.6	6.6
D 3	6.0	6.3	6.2
D 4	6.6	6.6	6.6
D 5	5.7	5.4	5.6
D 6	6.3	6.3	6.3
D 7	6.0	6.0	6.0
D 8	6.3	6.3	6.3
D 9	5.7	5.4	5.6
D 10	5.4	5.4	5.4
D 11	5.7	5.7	5.7
D 12	5.4	5.7	5.6
Mean	6.0	6.0	6.0

Table 8.4.5.1

The γ-background (μR/h) along the coasts of the Great Belt in 1970

Location	April	July	Mean
Agersø	5.1	4.8	5.0
Omø	4.9	5.1	5.0
Reersø	4.9	5.4	5.2
Reersø	5.4	6.0	5.7
Halskov	5.7	6.0	5.9
Sprogø	5.7	5.7	5.7
Knudshoved	5.1	6.0	5.6
Risinge	5.7	6.0	5.9
Fyns Hoved	7.1	6.3	6.7
Tårup Strand	6.0	6.0	6.0
Hov, Langeland	4.6	6.0	5.3
Mean	5.5	5.8	5.6

nuclear ships. An environmental γ-survey of the coastline along the Great Belt has therefore been initiated. Table 8.4.5.1 shows the results and table 8.4.5.2 the analysis of variance. The levels were a little lower than those found in other parts of the country. The annual mean was 5.6 μR/h.

It is remarkable that the lowest γ-background levels are found near the sea.

9. CONCLUSION

9.1. Risö Environmental Monitoring

No radioactive contamination of the environment originating from the operation of the research establishment was ascertained outside Risö in 1970. As in the previous years, the variations in contamination levels were quite independent of the distance of the sampling locations from Risö.

9.2. Nuclear-Weapon Debris in Air, Precipitation, Soil, Ground Water and Surface Water

The mean content of Sr-90 in air collected in 1970 was 0.0021 pCi Sr-90/m^3, i.e. 50% higher than the 1969 level. The average fall-out for the State experimental farms in 1970 was 1.6 mCi Sr-90/km^2 or 60% higher than the 1969 figure, and the mean concentration of Sr-90 in rain water was 2.4 pCi Sr-90/l, i.e. 10% higher than the 1969 level.

The accumulated fall-out down to a depth of 30 cm by the end of 1970 was approx. 55 mCi Sr-90/km^2. From 0-20 cm the level was 46 mCi Sr-90/km^2.

The fall-out levels in Jutland, in conformity with the greater amounts of precipitation in that part of the country, were 15-25% higher than the levels found in eastern Denmark.

The median level of Sr-90 in Danish ground water was 0.021 pCi Sr-90/l.

The median level of Sr-90 in fresh water from Danish streams was 0.45 pCi/l.

9.3. Sr-90 and Cs-137 in the Human Diet

The mean level of Sr-90 in Danish milk was 7.3 S.U., and the mean content of Cs-137 was approx. 14 pCi Cs-137/l.

The 1970 Sr-90 and Cs-137 levels were nearly equal to the levels found in milk produced in 1969.

The Sr-90 mean content in grain from the 1970 harvest was 41 pCi Sr-90/kg. The Cs-137 mean content in grain was 64 pCi Cs-137/kg. The Sr-90 level in grain from the 1970 harvest was nearly equal to the level found in the 1969 harvest, and Cs-137 was 50% higher than the 1969 level.

The mean contents of Sr-90 and Cs-137 in Danish vegetables collected in 1970 were 10 pCi Sr-90/kg (27 S.U.) and 4.6 pCi Cs-137/kg respectively, and in fruits 2.9 pCi Sr-90/kg and 12 pCi Cs-137/kg; potatoes contained 3.3 pCi Sr-90/kg and 12 pCi Cs-137/kg.

The mean levels of Sr-90 and Cs-137 in total-diet samples collected in 1970 were 8.1 S.U. or 14.1 pCi Sr-90/day and 30 pCi Cs-137/day respectively. From analyses of the individual diet components the Sr-90 level in the Danish average diet was estimated to be 7.3 S.U. and the Cs-137 intake to be 32 pCi Cs-137/day. The Sr-90 levels in the Danish total diet consumed in 1970 were a little lower than the 1969 levels, while the Cs-137 levels were a little higher.

Grain products contributed 31% and milk products 44% to the total Sr-90 intake, and 27% of the Cs-137 in the diet came from meat, 26% from grain products and 20% from milk products.

The Sr-90 as well as the Cs-137 diet levels were on the average significantly higher in Jutland than in eastern Denmark.

9.4. Sr-90 and Cs-137 in Humans

The Sr-90 mean content in human bone (vertebrae) collected in 1970 was 0.9 S.U. in new-born children, 1.9 S.U. in infants, 1.5 S.U. in children and teen-agers, 1.4 S.U. in adults (20-29 years old) and 1.2 S.U. in adults of more than 29 years. The 1970 bone levels were generally lower than the 1969 levels.

The mean content of Cs-137 in the human body in 1970 was estimated from whole-body countings to be 3.2 nCi (23 pCi Cs-137/g K), i.e. approx. 60% of the 1969 level.

9.5. Sr-90 in Sea Water

The mean content of Sr-90 in the inner Danish waters was approx. 0.6 pCi Sr-90/l in 1970, i.e. nearly the same as the levels in previous years.

9.6. The γ-Background

The γ-background measured at the State experimental farms in 1970 was 5.4 μR/h.

9.7. Summary

The annual Chinese thermo-nuclear test explosions since 1967 have stopped the rapid decrease of the environmental Sr-90 and Cs-137 levels observed in the first years after the test moratorium.

The concentrations of long-lived fall-out nucleides in ground-level air and precipitation collected in 1970 were considerably higher than the levels found in 1968 and 1969.

In milk produced in 1970 the Sr-90 and Cs-137 levels were nearly equal to the 1969 levels. In grain from 1970 the levels were equal to (Sr-90) or higher (Cs-137) than the 1969 concentrations.

The Sr-90 and Cs-137 levels in the total diet consumed in 1970 were a little lower (Sr-90) or nearly equal (Cs-137) to the 1968 and 1969 concentrations.

The Sr-90 concentrations in human bone were a little lower in 1970 than in 1969.

APPENDIX A

Calculated Fall-out in the Eight Zones in 1970

<table>
<tr><th colspan="2">Zone</th><th>mm precipitation in 1970</th><th>mCi Sr-90/km^2 in 1970</th><th>Accumulated mCi Sr-90/km^2 by the end of 1970 (0-30 cm)</th></tr>
<tr><td>I:</td><td>N. Jutland</td><td rowspan="4">789</td><td rowspan="4">2.14</td><td rowspan="4">58</td></tr>
<tr><td>II:</td><td>E. Jutland</td></tr>
<tr><td>III:</td><td>W. Jutland</td></tr>
<tr><td>IV:</td><td>S. Jutland</td></tr>
<tr><td>V:</td><td>Funen</td><td rowspan="3">666</td><td rowspan="3">1.27</td><td rowspan="3">53</td></tr>
<tr><td>VI:</td><td>Zealand</td></tr>
<tr><td>VII:</td><td>Lolland-Falster</td></tr>
<tr><td>VIII:</td><td>Bornholm</td><td>646</td><td>2.00</td><td>47</td></tr>
<tr><td colspan="2">Area-weighted mean</td><td>750</td><td>1.88</td><td>56</td></tr>
<tr><td colspan="5">The amounts of precipitation were obtained from ref. 9, and from 4.1 and 4.2.</td></tr>
</table>

APPENDIX B

Statistical Information

Zone		Area in km^2 13)	Population in thousands 13) 1965	Annual milk production in mega-kg 14) 1967	Annual wheat production in mega-kg 13) 1966	Annual rye production in mega-kg 13) 1966	Annual potato production in mega-kg 13) 1966	Vegetable** area in km^2 15) 1961	Fruit area in km^2 15) 1961
I:	N. Jutland	7,544	515	1,117	94	80	853	24	18
II:	E. Jutland	7,338	784	1,380					
III:	W. Jutland	10,764	579	976					
IV:	S. Jutland	3,984	230	515					
V:	Funen	3,482	425	494				25	38
VI:	Zealand	7,542	2,055*	604	306	56	119	39	45
VII:	Lolland-Falster	1,798	129	96					
VIII:	Bornholm	588	49	62					
Total		43,020	4,768	5,244	400	136	972	88	101

* 1,378,000 people were living in Greater Copenhagen and 677,000 in the remaining part of Zealand.

** Only horticultural holdings were included.

APPENDIX C

The observed Sr-90 and Cs-137 values were on the average 80% of the predicted.

We believe, as in 1969[1)], that this difference is due to an overestimate of the soil factors in the prediction models[17)].

Appendix C

A comparison between observed and predicted levels in the human food chain in Denmark in 1970

Nuclide and sample	Observed	Predicted	Equation used for the prediction
S. U. in milk	7.3	8.6	S. U. = 0.92 d(i) + 0.61 d(i-1) + 0.13 A by(i-1)
M. U. in milk	8.4	10.5	M. U. = 3.65 d(i) + 1.59 d(i-1) + 0.057 A by(i-1)
S. U. in rye	87	150	S. U. = 192 d(j-a) + 0.91 A by(i-1)
S. U. in barley	77	126	S. U. = 134 d(j-a) + 1.05 A by(i-1)
S. U. in wheat	93	151	S. U. = 157 d(j-a) + 1.30 A by(i-1)
S. U. in oats	55	73	S. U. = 67 d(j-a) + 0.72 A by(i-1)
pCi Cs-137/kg rye	85	114	pCi Cs-137/kg = 128 d(m-a)
pCi Cs-137/kg barley	56	88	pCi Cs-137/kg = 97 d(m-a)
pCi Cs-137/kg wheat	57	78	pCi Cs-137/kg = 86 d(m-a)
pCi Cs-137/kg oats	56	73	pCi Cs-137/kg = 80.5 d(m-a)
pCi Sr-90/kg potatoes	3.3	3.2	pCi Sr-90/kg = 0.17 d(j) + 0.059 A by(i-1)
pCi Cs-137/kg potatoes	12	9	pCi Cs-137/kg = 5.45 d(i)
pCi Sr-90/kg cabbage	12	13	pCi Sr-90/kg = 0.44 d(i) + 0.24 A by(i-1)
pCi Sr-90/kg carrots	20	14	pCi Sr-90/kg = 0.58 d(i) + 0.27 A by(i-1)
pCi Cs-137/kg beef	52	92	pCi Cs-137/kg = 34.9 d(i) + 2.8 d(i-1) + 0.64 A by(i-1)
pCi Cs-137/kg pork	63	88	pCi Cs-137/kg = 34.8 d(i) + 22.4 d(i-1) + 0.15 A by(i-1)
S. U. in diet	7.8	9.0	S. U. = 0.83 d(i) + 1.41 d(i-1) + 0.124 A by(i-1)
pCi Cs-137/day in diet	29	33	pCi Cs-137/day = 7.6 d(i) + 11.6 d(i-1) + 5.5 d(i-2)
S. U. in newborn bone	0.9	1.3	S. U. = 0.168 $d\frac{i+(i-1)}{2}$ + 0.031 d(i-2) + 0.021 A by(i-1)
S. U. in adult vertebrae	1.3	1.7	S. U. = 0.0245 $d\frac{i+(i-1)}{2}$ + 0.059 d(i-2) + 0.032 A by(i-1)
M. U. in adult body	23	41	M. U. = 8.8 $d\frac{i+(i-1)}{2}$ + 5.8 d(i-2) + 0.48 A by(i-1)

The prediction models were calculated from data collected 1962-68[17)].

d is the fall-out rate in mCi Sr-90/km^2. A is the accumulated fall-out in mCi Sr-90/km^2. (i) is the current year, (i-1) the year before etc. (j-a) is July-August and (m-a) is May-August.

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